USING AN ENERGY SYSTEMS APPROACH IN MODELING ACHIEVEMENT MOTIVATION AND SOME RELATED SOCIOLOGICAL CONCEPTS

By

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Dedicated to

our parents.

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Abstract of Dissertation Presented to the Graduate Council of the University of Florida in Partial Fulfillment of the Requirements for the Degree of Doctor of Philosophy

USING AN ENERGY SYSTEMS APPROACH IN MODELING ACHIEVEMENT MOTIVATION AND SOME RELATED SOCIOLOGICAL CONCEPTS

By

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Major Department: Curriculum and Instruction

The purpose of this study was to explore the usefulness of an energy systems approach to the analysis of systems in educational situations. The energy systems approach, as developed by H. T. Odum (1971), was examined and the symbolism (language) and laws of energetics were discussed in educational contexts. Procedures were identified whereby specified relationships between variables are represented by analog computer models and the behavior of the variables simulated over time.

Atkinson's (1965) achievement motivation theory was chosen as the basis for the educational system to be modeled using the energy systems approach. The concepts of locus of control, social pressure, and intensity of the learning situation were discussed and the relationship of these variables to the variables in the achievement motivation theory, as indicated by research studies, was added to the system. Achievement activity was considered as a variable separate from the retained information which resulted from achievement activity.

The relationships were combined in an energy language representation of the system, converted to differential equations, and put on an analog computer. The analog computer representation of the model

of the relationships enabled simulation of changes in the variables over different time periods.

The resulting simulations indicated that the model could reproduce the predictions and previous research findings which pertain to achievement motivation theory. Simulations over long time periods resulted in variable behaviors which indicated that motive to avoid failure was not a relatively stable personality characteristic as had been postulated. Motive to succeed remained relatively stable during long or short simulated time periods. The relationships between probability, incentive, and motive functioned as predicted in the theory, regardless of the simulated time period.

The variables probability of success, locus of control, retained information, and intensity of the learning situation were changed in different simulations to determine the effect of different starting conditions on the outcome of the simulation. For conditions of high motive to succeed, intermediate levels of the four manipulated variables tended to result in greatest initial increase in retained information, continued maintenance of achievement activity, and general decline of motive to avoid failure and tendency to avoid failure. When the manipulated variables were examined under conditions of high motive to avoid failure, the general depreciation of all variables was noticed except when the intensity of the learning situation was very high. In this case, the conditions of general decline in the variables over time changed to a condition of stability and performance similar to the type of variable behavior common to high motive to succeed conditions.

The behavior of the variables indicative of success (when

motive to succeed was high) was the oscillatory behavior of achievement activity, probability of success, retained information, locus of control, and motive and tendency to succeed. The oscillations were not found to occur at the same time but were consistently found to have a time lag. Retained information increased after achievement activity increased, and achievement activity increased after the probability of success changed.

The implications of the findings from the simulations were discussed and the procedures necessary to verify the findings of the simulation were indicated. As well, the implications of the findings for experimental design and theoretical investigation, should the modeling procedure prove valid and reliable, were discussed.

CHAPTER I

THE PROBLEM

Introduction

Recent literature in educational research has included work which utilizes causal models (Harriott and Muse, 1973; Madaus, Woods, and Nuttall, 1973; Anderson and Evans, 1974). The purpose in using causal models was to enable the researchers to examine the structure of relationships among variables which affect outcomes of interest in educational situations. Attention has been given to causal models because the approach "appear(s) to have some utility in charting unexplored areas, such as those currently being encountered in the study of educational effects at system levels" (Harriott and Muse, 1973:225).

Some inadequacies of causal models limit the technique, especially at the system level. First, since causal analysis utilizes multiple linear regression, one assumption is that the relationships between factors affecting the outcomes are linear. The Dods-Yerkes Law of Motivation and the concepts involved in the theory of achievement motivation (Atkinson, 1965) are examples of instances where the relationship of predictors to performance is not linear. Second, the mechanism with which factors interact to produce the outcomes are not specified in the causal models. Factors may be influential only at certain times or for certain levels rather than in some linear or constant relation. Third, the effect of feedback is a crucial part of

systems. When feedback occurs, the changes it produces in relationships may differ from the relationships originally established. Finally, the causal models currently used in educational situations have been dependent on data which pertain to one time frame or particular situation. Since many of the factors in learning are time dependent, it is also necessary that the relationships among variables pertain over time. However, it is often economically and logistically infeasible to perform many replications under varying conditions in order to examine the limits of relationships. The model, then, has usefulness as a factor in the clarification of relationships and the limits imposed on them as well as for identifying hypotheses for further investigation.

A more recent technique for studying the relationships among variables, which responds to the limitations imposed by necessity, is an energy approach developed by Odum (1971). The mechanisms by which facotrs interact are specified. The relationships may be linear or non-linear. Relationships between variables may be examined over time. Finally, the effects which variables have on each other due to feedback can be examined. Using analog computer techniques, the mathematical representation of the model may be simulated, thus indicating the changes occuring in the variables over time due to the specified relationships. Factors which affect outcomes may be kept constant or allowed to vary. Information about the behavior of variables under various conditions can be used to determine whether the model yields the same results as are known to pertain under the conditions specified. Hypothethical constructs may be inserted into the model to ascertain how they vary when other variables behave as demanded by evi-

dence available. The model thus takes into account the dynamic nature of systems by including feedback, the effect that variables have on each other, the changes which result because of the interactions due to relationships between the variables, and the effect produced as these relationships vary over time.

Definition of the Problem

The purpose of this study was to explore the usefulness of Odum's energy systems approach, which was developed in an ecological context, to modeling educational situations by:

1) applying the concepts of the technique to some aspect of the learning process in order to formulate a model.

2) examining the model in light of what is currently known about the behavior of the variables chosen in order to establish the degree to which the model replicates known behavior of the variables

3) identifying interactions and relationships within the model which may yield fruitful results in empirical investigations.

The Energy Systems Approach to Modeling

Energy is the common denominator for an examination of all systems and the principles of energetics, the rules by which the systems operate. Energy flows cause changes whose effects we can see in many instances. Energetic principles determine how these flows interact, the characteristics the system requires for energy storage and dissipation, and the characteristics of the system which determine efficient energy utilization and system stability. Processes which take place within human systems are also required to take place within the specifications which we know pertain whenever energy is involved. Metabolic processes supply energy for body functions. Neural processes require

electrical energy in order to function. Information is itself a high grade energy since it enables or manages energy flows in order to accomplish work in a physical sense, or to solve problems, create concepts, and modify stored information.

In order that energy interactions can be discussed and the energy changes understood explicitly, Odum (1971) developed a specialized symbolism. The symbols, their use in model construction, and some of the energetic principles inherent in this type of model are the basis for the following discussion. Since an energy approach to modeling educational situations or systems is a new one, the following section will serve two functions: to describe the symbolism involved in this modeling technique, and to translate energy language concepts into educational contexts.

Energy flow in the model is always considered as a proportion of the total energy which could theoretically flow. The total energy theoretically possible can be given the quantity assignment of 1. Then, if the energy flow is only one-half of the possible flow, the energy flow would be half of the total possible, or .5 . By making this assumption about energy flows, relationships can be expressed in a fashion which allows easy translation to equations used in representing the model on an analog computer.

Energy flows are represented symbolically as lines. When two flows intersect, the two energy flows interact with one another. The simplest intersection is one in which one flow joins another as shown in Figure 1.

Figure 1: Simple Intersection of Energy Flows

When flow A intersects flow B, the interaction is said to be additive. The resulting flow, C, is the sum of flow A and flow B. For example, flow A could be considered as teacher effort, flow B as student effort. The resulting energy, C, is the sum of teacher and student effort or energies.

Other intersections of energy flows are slightly more complex and the interaction of the two flows with each other produces different results, depending on the nature of the intersection. Some of the more complex energy intersections can be represented by the symbol shown in Figure 2a. Within the 'arrow', another symbol indicates the type of interaction which occurs. Two types of interactions will be discussed, one of which is shown in Figure 2b.

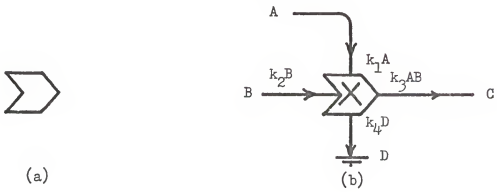

Figure 2: Multiplicative Energy Interactions

The interaction of flow A with B in Figure 2b is said to be multiplicative. This means that flow C is proportional to flows A and B, or $C = k_3AB$. If A were to increase, and B remain constant, flow C would increase in proportion to the increase in A. The constants (k's) represent the proportion of the total possible flow which is being represented by this intersection. k_4 is a constant which includes the effect of k_1 and k_2 (any number of constants multiplied together produce one constant). Whenever two energy flows intersect, some energy is necessary to make the interaction possible. The energy making the interaction of flow A with B possible is flow D. It is shown as dissipated energy which is no longer available to do work.

As an example of the interaction shown in Figure 2b, flow A could be considered as the effect of IQ and flow B the effect of previous learning. The interaction shown in the diagram then indicates the IQ and previous learning interact in such a way that the new flow, C (or the effect of the combination of the two flows) is dependent upon the magnitude of both IQ and previous learning. Should either increase, the effect of the two combined increases.

Another type of interaction which is possible when two energy flows intersect is shown in Figure 3.

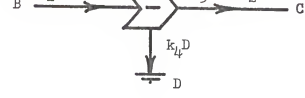

Figure 3: Inverse Multiplicative Energy Interaction

The minus sign in the symbol showing the interaction indicates an inverse relationship. If flow B is kept constant, then an increase in flow A is meant to cause a decrease in the resulting flow C. Since the maximum flow possible from A is 1, the $1 - k_2A$ gets smaller as the flow from A approaches maximum. Multiplying flow B by $(1 - k_2A)$ then results in a decrease in C when A increases, as can be seen in the equation $C = k_3B(1 - k_2A)$. If flow A remains constant, then an increase in B results in an increase in C.

As an example of the interaction, flow A could be considered as the effect of inhibition, and flow B the tendency to participate. Then, as inhibition increases, the combination of the tendency to participate and inhibition decreases. Increases in the tendency to participate result in an increase in the effect produced by the combination of the two.

Several energy flows may interact to produce one flow. This is shown in Figure 4. In Figure 4a, the resulting flow, D, is proportional to the magnitude of each of the interacting flows. In Figure 4b, the resulting flow, H, is proportional to the magnitude of flows E and F and inversely proportional to the flow of G. Any number of these may interact with one another to produce a new flow.

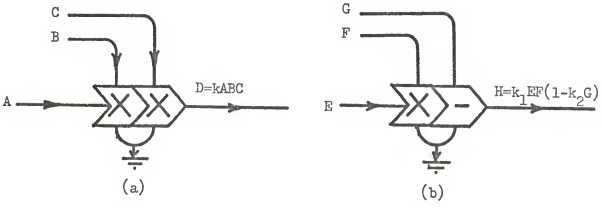

Figure 4: Interactions of Several Energy Flows

Energy flows may originate within the system being studied or outside of the system. If they originate outside the system, they are termed 'forcing functions' and are represented symbolically as shown in Figure 5.

Figure 5: Forcing Function Symbol

Energy flows originating within the system come from 'tanks' or 'state variables'. These represent storage functions and are symbolized as shown in Figure 6.

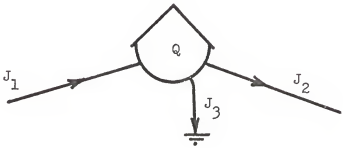

Figure 6: Storage Function Symbol

The quantity of energy stored at any given instant is dependent on the energy flows leaving storage and going into storage, as well as the initial quantity of stored energy. In Figure 6, the flow into Q is J_1, the flows out are J_2 and J_3. While J_2 represents an energy flow which is capable of interacting with another flow or of increasing the

quantity of energy in another storage, J_3 is energy which is dissipated. Dissipation of energy refers, in this case, to the removal of some energy from the energy which can facilitate transfer, interactions, and be stored. The energy which is stored depreciates over time and is, therefore, less able to interact, transfer, or be stored. J_3 indicates this depreciation. The amount of dissipated energy (depreciation) depends on the magnitude of the stored energy. The magnitude of flows into or out of storage which do not represent dissipated energy depends on the interactions which take place between storages.

In an educational context, any quantifiable variable can be represented by a state variable, or 'tank', if what it represents varies with increased input or output, or is free to depreciate or dissipate with time. Thus, learning could be considered as a state variable, dependent on what is put into it, able to influence other operations or interactions, and also depreciating over time. If no energy or flow is put into learning, or the flows in are less than the depreciation, we find that forgetting occurs -- the energy becomes less and less useable as more of the energy depreciates.

In modeling a system, principles of energetics are brought to bear on the total system. The energy dissipated when energies interact, when flows move from one storage to another, or when energy depreciates is shown symbolically in Figure 7.

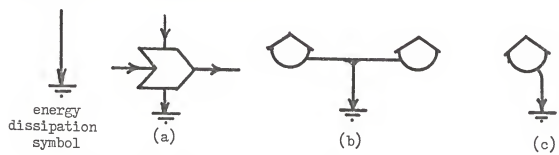

Figure 7: Representations of Energy Dissipation

Energy dissipated represents the energy necessary to facilitate interactions (Figure 7a), transfer energy (Figure 7b), and depreciation (Figure 2c). Every energy flow along a path requires energy be used to make the flow possible. This energy dissipation is included in the constants which accompany each flow (as was shown in Figures 2 and 3b). The energy dissipation symbol for energy which facilitates flow usually does not appear in the diagrammed model in order to avoid complicating the diagram with excessive lines. An exception is that transfers of energy from one storage to another without any interaction include the dissipation symbol in the manner shown in Figure 7b.

If the energy coming into the system is increased, the system must utilize the energy -- it cannot be dissipated without first facilitating some occurrence. Therefore, the system must absorb the energy by increasing storage or by building new structure. In an educational context, an energy source outside the system might be anxiety, and the system on which anxiety is operating may be considered as motivational structure in an individual. The system can cope with certain amounts of anxiety. However, if the anxiety input becomes large, the system cannot utilize this energy with the structure that exists. The energy may then be utilized to build some new structure within the system so that the extra energy may be utilized. This new structure could be referred to as a defence mechanism.

The role of feedback or energy loops in the system is very important in bringing about the efficient use of energy. Small amounts of energy, when utilized in the system, can have a large effect. Stable systems have many feedback loops; in fact, the utilization of small

amounts of energy to increase energy flow upstream is what provides stability. Consider the example shown in Figure 8. The external source of energy, I, is a constant energy source (I = k). Flow J_1 is the result of the interaction of flow I with flow J_2, or, $J_1 = kIJ_2$. If I = 1000 and J_2 = .01, then J_1 = k x 1000 x .01 or 10k. Increasing J_2 to .02, J_1 = k x 1000 x .02, or 20k. Flow J_2 has, in effect, acted as the valve which limits how much of I reaches Q. By increasing J_2 a very small amount (.01), J_1 has been doubled.

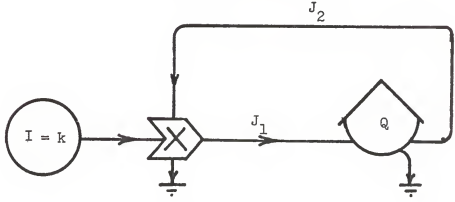

Figure 8: Feedback Loop in a System

If J_2 were not put into the interaction with I but just allowed to drain energy to another storage, or another system, J_1 would always remain constant (in this case J_1 = kI). When flow J_2 to another system is larger than J_1 into Q, the storage in Q would decrease to zero. Thus, an energy flow back into the system can help regulate energy flow according to need.

It is useful to examine power within systems, this being the rate of flow of useful energy. In successful systems, the Darwin-Lotka Law operates (Odum, 1971). Lotka's principle states "that whenever it is necessary to transform and restore the greatest amount of energy at the fastest possible rate, 50 percent of it (energy) must go down the

drain" (Odum, 1971:31). The drain referred to energy which is dissipated in order to make the transformation possible. A graph of power versus energy dissipated is shown in Figure 9. Darwin's concept of natural selection identifies successful individuals as those who adapt to their environment. Combining these two, the Darwin-Lotka Law indicates that those systems which maximize power are the systems which are most likely to succeed. Feedback loops are a means for maximizing power within a system. When new structure is added to a system, its utility to the system depends on whether the structure feeds back to the system in such a way that power is maximized for the system.

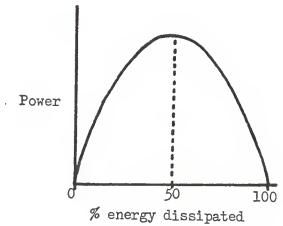

Figure 9: Graph of Power Versus Energy Dissipated

Lotka's principle is of special value in some facets of education. In achievement motivation theory (Atkinson, 1965), the tendency to achieve and the tendency to avoid failure are greatest when the probability of success is .5 or 50 percent. The Dods-Yerkes relationship for optimum motivation is a curve like that shown in Figure 9 except that performance replaces power and amount of motivation replaces energy dissipated. Thus, there is an indication that the maximum power principle may be considered to be operating in educational

systems as well as ecological ones.

In some instances, energy flows only occur under certain conditions. For example, energy may flow from a 'tank' only if the quantity of energy in the 'tank' is greater than some other 'tank' or greater than a specified value. In this case, two energy values must be compared. Figure 10 shows the comparison of the amount of energy Q in the 'tank' with a constant K. This is shown with a comparator symbol. The comparator subtracts the value of K from Q. If Q is greater than K, then the result of the subtraction is positive in value and the output of the comparator is 'logic 1' (or true). When an output of logic 1 is the input for switch 'S', then energy is allowed to flow. If Q is not greater than K, then the subtraction results in a negative value so the output of the comparator is 'logic 0' (or false) and the switch remains open so no flow occurs. Two 'tanks' can be compared by putting the other tank in place of K.

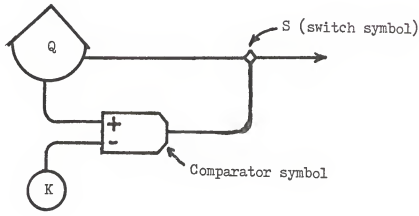

Figure 10: Use of a Comparator in a System

It may not be necessary to compare several conditions; for example, energy may only flow within some interval of values.

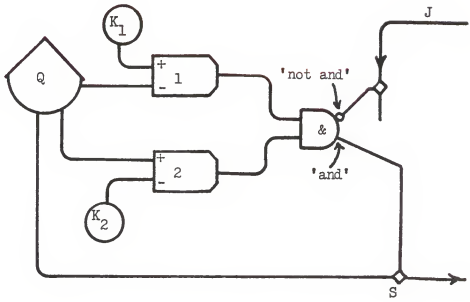

Figure 11: Comparators and And Gates in a System

Figure 11 shows a comparison in which the value of Q must be less than K_1 and greater than K_2 in order for energy to flow from Q. If Q is less than K_1, the output of comparator 1 is 'true'. If Q is greater than K_2, the output of comparator 2 is 'true'. The 'and symbol' puts out logic 1 (true) only if both inputs are logic 1 or true. Therefore, the switch, S, is only closed when the conditions stipulated are satisfied. It may be a requirement for some other flow, J, to occur only when the flow from Q does not occur, that is when Q is greater than K_1 or Q is less than K_2. In this case, when either of the signals from the comparators is not logic 1, the 'not and' condition is true (logic 1) and it can cause the close of the switch facilitating flow J.

When models are constructed utilizing the principles stated, they are originally presented using the symbolism discussed. Additional symbols for interactions not discussed in this study are found in Odum (1971). Odum's symbols are only one way to represent the model; however, it is an efficient way to present relationships pictorially

and an aid to determining the mathematical representation of flow of energy in the model. In order to examine the effect of energy flows and interactions over time, the model can be converted into a mathematical model, and then to an analog computer model. Using the computer, variables and relationships can be evaluated over time, flows manipulated, and the changes in variables plotted graphically.

Figure 12 shows a simple model in 'energy language' symbols. Energy source A provides a constant flow of energy from outside the system. One flow, k_3Q, is a flow to another system or storage not considered in this model. Flow into Q is k_1AQ and flow out of Q in the loop to the intersection is k_2AQ. k_1 and k_2 are different, to indicate different flows. The product, AQ, appears in both flows because both flows depend on how large Q is and how large A is. If either A or Q were to become zero, there would be no flow at all.

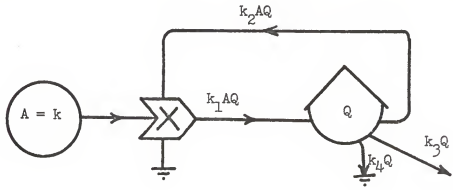

Figure 12: Simple Energy Model

The mathematical representation of the model requires only that the changes which take place in the state variable be considered. These changes are the sum of the flows into the 'tank' minus the flows out of the 'tank'. The flows are expressed in terms of the relationships so that all relationships are included in the mathematical model.

The change in Q over time ($\dot{Q}$) is given by a differential equation. For this model, the equation is:

$$\dot{Q} = k_1AQ - k_2AQ - k_3Q - k_4Q$$

One equation is necessary for each 'tank' or variable.

The final representation of the model is the analog computer version of the differential equations. In this model, all of the flows can be manipulated by manipulating the constants (k's), and the graphs of the change in Q over time plotted using the computer. The computer makes possible simultaneous manipulation of many relationships while presenting for inspection changes in variables in a manner which we can comprehend -- one or a few at one time.

The crucial part of the modeling procedure is to determine what relationships exist among the variables in the system being considered. Relationships determine energy flows, and the energy flows determine the changes in the variables. Therefore, the relationships indicate what happens, the mechanism by which it happens, and the variables which are affected, as well as the energy sources outside the system.

General Hypotheses

The model which was constructed used as its basis a theory which has been useful in the investigation of achievement-oriented activities. The behavior of the model was examined in light of relationships which we know exist, at least in some combinations with each other. The hypotheses, then, were:

1) That the energy systems approach to modeling can be used to model the selected educational system.

2) That the model is useful in investigating combinations of relationships which have not been empirically investigated, providing an indication of what might be expected to occur.

3) That the model can be useful as an hypothesis-generating instrument.

4) That energy systems models can be useful for theoretical speculating about relationships between variables in educational situations.

CHAPTER II

THE RELATIONSHIPS TO BE MODELED AND THE MODEL

The Relationships

The theory of achievement motivation (Atkinson, 1965; Atkinson and Feather, 1966) has been a useful guide for research in areas concerned with motivation and achievement in academic situations. Bower, Boyer, and Scheirer (1970), in a review of research related to achievement motivation, identified more than one thousand studies related to this theory. The theory also embodies relationships which have been identified in the energy approach to modeling. The discussion of the relationships has been divided into two sections. In the first section, the relationships existing between variables in achievement motivation theory are presented. The second section adds some other relationships which current research suggests affect achievement and motive to achieve, and which can be incorporated into the original theory.

The Achievement Motivation Theory

Atkinson (1965) postulated that whether or not an individual possesses the tendency to undertake achievement-oriented activities is dependent on the tendency to achieve success (T_s) and the tendency to avoid failure (T_f). If T_s is greater than T_f, achievement-oriented activities will be attempted. If T_f is greater than T_s, such activity will be avoided. The definition of tendency to succeed and tendency to avoid failure which yield the relationships among the determining variables is therefore necessary in order to determine whether or not the

tendency to enter achievement-oriented activities will exist.

The tendency to achieve success is defined to be the multiplicative relationship of three variables -- the motive to achieve success (M_s), the probability of success (P_s) and the incentive to succeed (I_s). This relationship can be stated mathematically as $T_s = M_s \times P_s \times I_s$. The motive to succeed is considered in the theory to be a relatively stable personality characteristic. Probability of success is the likelihood of success which the individual perceives as the case if he were to undertake the activity. Incentive to succeed is defined in the mathematical relationship $I_s = 1 - P_s$. Very easy tasks have low incentive value because there is a high probability of success, whereas more difficult tasks have higher incentive value. The basis for assigning this definition to incentive resulted from research done by Atkinson (1958) to determine the relationship between incentive to participate and expectancy of success.

Expressing motivation as a function of motive, expectancy, and incentive was suggested by Tolman (1955). Atkinson's use specified these factors and their relationship more rigorously as two levels -- tendency to succeed and tendency to avoid failure. Motive to succeed is usually inferred from the Thematic Apperception Test score. Work by Lesser, Krawitz, and Packard (1963) and French and Lesser (1964) supported the assumption that motive to succeed is successfully inferred from TAT scores and is related to high achievement motivation.

The tendency to avoid failure is also defined as the multiplicative relationship between three variables. These are the motive to avoid failure (M_f), probability of failure (P_f), and the incentive to avoid failure (I_f). The relationship is shown as $T_f = M_f \times P_f \times I_f$.

The motive to avoid failure is considered as a relatively stable personality characteristic which is expressed in the emotional reaction called anxiety. Raphelson (1957) presented evidence which suggested that anxiety as a measure of avoidance motive, determined by the Mandler-Sarason Scale of Test Anxiety, was indeed feasible.

Incentive to avoid failure is defined mathematically as $I_f = -P_s$ in keeping with Atkinson's (1958) findings. The negative value is meant to indicate the tendency to avoid failure, and hence a negative tendency to approach achievement-oriented activity. Relating incentive to avoid failure to the probability of success makes the incentive to avoid failure highest when the probability of success is greatest. Therefore, the tendency to avoid failure, because it is a part of a multiplicative relationship, becomes a more important factor if the motive to avoid failure increases. For highly anxious people, the result is a high tendency to avoid achievement-oriented activities even though the task may be perceived as easy.

The postulated relationship between probability and incentive is such that the product of the two is greatest when the probability of success (or failure) is .5 . This relationship is shown graphically in Figure 13.

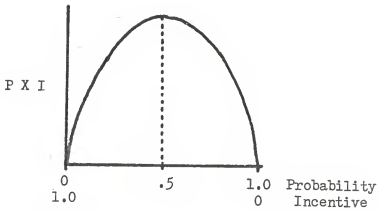

Figure 13: Relationship Between P_s, I and P x I

Both the tendency to achieve and the tendency to avoid failure are greatest when the task is perceived to be of intermediate difficulty. Since $P_s \times I_s$ and $P_f \times I_f$ are equal at any given set of values, then the tendency to succeed will be greater than the tendency to avoid failure only if motive to succeed is greater than motive to avoid failure. This basic postulate in achievement motivation theory has been utilized successfully as a predictor in acheivement-oriented activity (Bower, Bayer, and Scheirer, 1970; Aronoff and Litwin, 1971; Clifford and Cleary, 1972).

The role of extrinsic motivation in the theory is important with respect to those persons for whom the motive to avoid failure is high. These persons sometimes participate in achievement-oriented activity even though the tendency to avoid failure is very high. To meet this contingency, Atkinson (1965) postulated that extrinsic motivation can be considered as a motivation to participate in the activity, perhaps in order to comply with authority, seek approval, or as a result of interest or curiosity. When the extrinsic motivation is at a high level, the strength of the tendency to participate in the activity can be considered as the difference between the extrinsic motivation and the tendency to avoid failure. In this case, the tendency to participate is greatest at extreme probabilities of success, as shown in Figure 14.

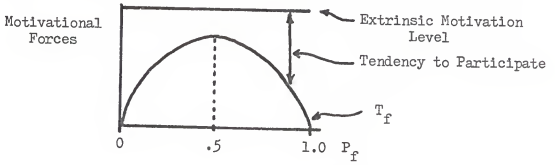

Figure 14: Motivational Forces as a Function of P_f.

The theory predicts that success or failure in an achievement-oriented activity affects the probability of success in successive activity. If a person succeeds in an achievement situation, the probability of success in that activity is increased and incentive decreases. Conversely, if an attempt results in failure, the probability of success for that activity decreases and incentive increases. This results from the relationship between incentive and success presented in the theory.

The theory also predicts that those persons for whom the tendency to succeed is dominant ($T_s > T_f$) are likely to choose tasks of intermediate probability of success since this is the region in which tendency to succeed is maximized. Persons for whom the tendency to avoid failure is dominant are likely to choose tasks which are either very easy or very difficult (high or low probability of success). By referring back to Figure 13, it is evident that P x I is smallest at low or high probability of success. Tasks of this nature minimize the tendency to avoid failure and are, therefore, preferred because motive to succeed is not great enough to overcome motive to avoid failure. Studies by Atkinson and Litwin (1960), Reid and Cohen (1973), and Aronoff and Litwin (1971) supported the predictions.

Predictions using the theory can be made about the effect of success or failure on the persistence which each type of person exhibits in a given situation. If the tendency to avoid failure is dominant, success at very simple tasks (high P_s) increases the probability of success. This further reduces the tendency to avoid failure and, therefore, encourages persistence at the task. If this person fails at the simple task, probability of success decreases toward intermediate levels. The tendency to avoid failure increases and the person tends to avoid any further activity.

Persons for whom the tendency to succeed is dominant do not tend to persist long at a task. Either success or failure results in a probability of success which moves away from intermediate levels of success and reduces the tendency to succeed. However, success interspersed with failure can keep the probability of success at intermediate levels and increase persistence.

Atkinson and Litwin (1960) examined the relationship of achievement motivation theory and found that individuals high in tendency to succeed chose intermediate risk activities and did not persist as long as high anxious individuals who chose either very simple or difficult tasks. Findings of Feather (1961, 1963) also indicated that the achievement motivation theory was a good predictor of persistence.

The relationships, as specified by the theory, can be restated as relationships which are to be modeled. This restatement results in mathematical descriptions which are equivalent to those in the theory, even though they may seem to differ at first examination. For example, incentive is related to probability of success, so all incentive values can be stated in terms of the probability variable.

In summary, the relationships which make up the achievement motivation theory are:

1. The incentive to succeed decreases as the perceived probability of success increases. $I_s = 1 - P_s$.

2. The incentive to avoid failure is equal in magnitude to the perceived probability of success. The negative value indicates avoidance of the task. $I_f = - P_s$.

3. The perceived probability of failure decreases as the perceived probability of success increases. $P_f = 1 - P_s$.

4. The tendency to succeed is greatest at intermediate probability of success and increases as motive to succeed increases. The relationship is multiplicative such that $T_s = M_s \times P_s \times (1-P_s)$.

5. The tendency to avoid failure is greatest at intermediate probability of success and increases as the motive to avoid failure (anxiety) increases. The negative value of this relation indicates avoidance. The relationship is multiplicative such that $T_f = M_f \times (1-P_s) \times (-P_s)$.

6. When the tendency to succeed is greater than the tendency to avoid failure, achievement-oriented activity is likely to be attempted. In this case, tasks are chosen for which the perceived probability of success is intermediate, that is, tasks which maximize the tendency to succeed.

7. When the tendency to avoid failure is greater than the tendency to succeed, achievement-oriented activity is likely to be avoided.

8. When the tendency to avoid failure is greater than the tendency to succeed, and there is a high level of extrinsic motivation, achievement-oriented activity is likely to be attempted. Tasks are chosen for which the perceived probability of success is very low or very high in order to minimize the tendency to avoid failure.

Some Other Pertinent Relationships

The utility of achievement motivation theory may be enhanced by the addition of other relationships which affect the variables central to achievement motivation -- motive and probability of success. The purpose of this section is to identify some relationships which are relevant to the variables of motive and probability of success and

which can be integrated into achievement motivation theory.

Perceived ability may influence tendency to participate in academic achievement situations. Crandall (1969) identified the individual's perception of his skill as determining his expectancy of success in a situation. Reid and Cohen (1973) found that those high in need to achieve attributed success to ability. Weiner (1970) reported that high need achievement individuals ascribed failure to the lack of effort on their part, whereas individuals low in need to achieve ascribed failure to lack of ability. Retention is a more general term which could include perceived ability, perception of skills pertinent to the situation, and the accumulation of successes and failures which affect changes in probability of success, as mentioned in achievement motivation theory.

Achievement motivation theory is dependent to a large extent on the motive to succeed and the motive to avoid failure. Both are considered in the theory to be relatively stable personality characteristics. In Atkinson's (1965) work, in which he stated the theory, motive to succeed was inferred from the Thematic Apperception Test and motive to avoid failure inferred from the Mandler-Sarason Test Anxiety Questionnaire. These motives were thought to be relatively unconscious and their strength inferred from measures related to the motive.

Holmes (1971) found that students were able to give self-reports of tendency to achieve success which were significant predictors of academic success. He concluded that this was an indication that the relatively stable personality characteristics were not really as much of an unconscious trait as had been postulated. There appear to be some features of motive to succeed or to avoid failure which are

dynamic within the individual, or at least traits which are partially changeable at the desire of the individual.

Rotter (1966) considered the relationship of internal and external locus of control with the need for achievement to be relevant. Those persons who were identified as having an internal locus of control (internals) believed that their actions are of some consequence in determining the outcome in a given situation. Persons having an external locus of control (externals) believed that the outcome is not affected by their actions but is only governed by fate or chance. Measures of locus of control indicated that it is not dichotomous, but rather an internal-external continuum. Considering locus of control as an expectancy variable, as suggested by Lefcourt (1966), and bearing in mind that Atkinson (1965, 1966) refers to achievement motivation theory as an expectancy-value theory, the existence of a 'theoretical bridge' between locus of control and achievement motivation theory can be constructed.

Clarke (1973), in reviewing measures of achievement motive, identified as a consistent finding that achievement-oriented individuals had a sense of competence, hope of success, and internal locus of control. Hersh and Schiebe (1967) found internals to be active, striving and independent, as identified by comparing internals and externals on personality measures. Crandall and Lacey (1972) reported that internality correlated highly with performance in achievement situations. High measures of internality were usually accompanied by high achievement. Further evidence that internality and high tendency for achievement are related was given in a study by Reid and Cohen (1973). They found that individuals high in need to achieve attributed success to their ability

and to internalized motivation. Weiner (1970) found that those high in the need to achieve ascribed failure to lack of effort, indicating that they feel that they can influence the outcome if they put enough effort into exerting this influence. Studies by McGhee and Crandall (1968) and Bartel (1971) also confirmed the finding that those persons who were considered high internals performed better in achievement-oriented situations.

Since findings indicated that internality is related to motive to achieve, it seems reasonable that externality is related to motive to avoid failure. Mehrabian (1969) found that low achievers were more anxious than high achievers. Lefcourt (1966) found that externals experienced more debilitating anxiety. Crandall (1969) suggested that low expectations may underlie anxiety. These findings indicated that externality and the relationship of anxiety to the motive to avoid failure affect achievement motivation in the same fashion. A review of locus of control measures by Joe (1971) further substantiated the existence of such a relationship in that he found consistency in reports that externals were more anxious to avoid failure than internals.

In achievement motivation theory, past performance resulted in changes in the consequent probability of success. Relationships of performance with locus of control may exist as well. Clifford and Cleary (1972) found that internals perform at a higher level when given a choice of tasks of varying difficulty. Further, the choice of tasks followed what would be expected from achievement motivation theory -- that those with high tendency to succeed chose tasks of intermediate level of difficulty, while those who had a high tendency to avoid fail-

ure chose easy tasks. Rotter (1966) and Crandall (1969) also suggested that behaviors influenced by locus of control are strengthened when outcome is contingent on behavior. Raynor and Rubin (1971) found that students who had a high motive to succeed performed best when their behavior in one situation was influential in determining further activity. Internality seems, therefore, to be related to motive to succeed, and that success or failure in a task affects locus of control as well as the perceived probability of success.

In the review by Joe (1971), there was some indication that the concept of locus of control was not entirely free of social desirability effects. Hersh and Schiebe (1967), in examining the reliability and validity of locus of control as a personality dimension found that persons classed as externals might perceive their actions of little importance because the actions of others around them determined the relevance or irrelevance of their efforts. McGhee and Crandall (1968) found that locus of control was a better predictor of grades received than of performance in standardized achievement tests. This may indicate that individuals used social comparison effectively in determining outcomes, since grades in a class are generally assignments of relative standing within a class.

Atkinson (1965) had alluded to social comparison and its effect on achievement in introducing the concept of extrinsic motivation. In Holmes' (1971) study, in which students were able to give self-reports of motive to achieve, the students used their peers as reference in making their predictions. Veroff (1969), in discussing the development of motive, distinguished between autonomous or internal motive and social motive. His studies led him to believe that social comparisons become

important in achievement-oriented activity between ages six and nine. A reinforcement hierarchy suggested by Forness (1973) puts social approval high on the scale, thereby indicating that it influences the effect of previous performance in the determination of further activity.

In light of the research findings, other relationships which can be included in the model to be constructed are:

1. An increase in locus of control produces an increase in internality.

2. As locus of control increases, motive to avoid failure (anxiety) decreases.

3. As locus of control decreases, motive to succeed decreases.

4. As locus of control increases and retention increases, the perceived probability of success increases.

5. Social pressure is equivalent to extrinsic motivation in the relationships stated in the achievement motivation theory.

6. Social pressure will influence the individual to participate in achievement activity only if locus of control is low.

7. Success in achievement activity increases locus of control.

The Model

Explanation of Energy Symbol Representation

Using an energy approach in modeling achievement motivation and related concepts results in modeling only a small portion of the total energetic occurrences in the human body, or the mind. Energy for the processes modeled is supplied from metabolic processes which are essentially external to the system considered and, therefore, is a forcing function. If energy supplied to the process were available only in small amounts it would be necessary to include the energy

which makes the processes possible. However, it was assumed that the energy making the processes possible was available as required, that is, that the process was limited only by the occurrences within the system and not by available energy external to the system modeled.

Figure 15a shows how energy which is supplied externally to the system to make the processes occur can be represented.

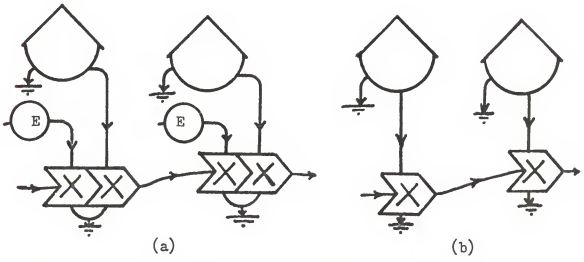

Figure 15: Alternate Representations Used in the Model

Since this energy is supplied for all interactions and is supplied in the quantity necessary, Figure 15b shows an equivalent representation in which the energy supplied (E in Figure 15a) is assumed and not diagrammed. This does not change what happens in the interactions because this energy is not a limiting factor. The result is also a slightly simpler diagram, and hence, in diagrams for this study, it was assumed that the energy existed and the symbol omitted as in Figure 15b.

As an aid to explaining the energy symbol model, Figure 16 shows a schematic representation of the model. This schematic is meant to give a general explanation of how the model is conceptualized. The

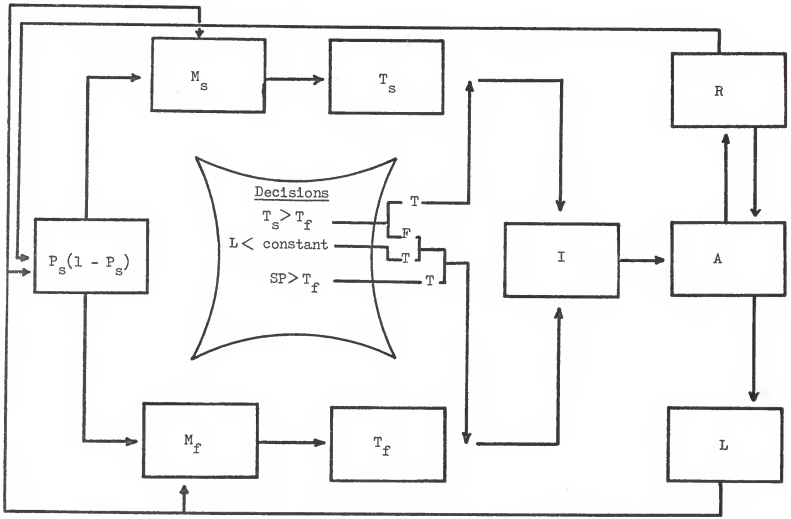

Figure 16: General Schematic of the Model

achievement motivation theory stated that the tendency to succeed (T_s) was the result of the multiplicative relationship of probability of success (P_s), incentive ($1 - P_s$), and motive to succeed (M_s). Likewise, the multiplication of probability of success, incentive, and motive to avoid failure (M_f) produced the tendency to avoid failure (T_f). These relationships are shown in the schematic beginning at $P_s(1-P_s)$ and proceeding up and right for $M_s \times P_s(1-P_s)$ and down and right for $M_f \times P_s(1-P_s)$.

Certain decision processes then determine interaction with the learning situation. If ($T_s > T_f$) is true, then tendency to succeed is dominant. The schematic indicates that the tendency to succeed interacts with I. I represents the intensity of the learning situation. Here intensity was defined as the combination of factors such as sequence, strength of stimulus, and task complexity which influence the valence of the learning situation presented. I was an attempt to represent those aspects of the learning situation which affect acquisition and performance, and not meant as a specific breakdown of particular aspects of presentation in learning situations. This aspect was considered in the model as an external force on the individual, although this is not shown in the schematic. Because it was an external force, it was only of interest in that an increase in intensity fosters greater interaction of the learner with the situation.

If ($T_s > T_f$) is false, that is, $T_f > T_s$, then other decisions must be made. Locus of control (L) must be less than some stipulated threshold value which determines 'low' locus of control. Social pressure (SP) must exceed the tendency to avoid failure. Social pressure, in this case, included extrinsic motivation referred to by

Atkinson as well as peer group pressures and pressures arising out of social norms. When these conditions are satisfied, the individual interacts with the learning situation to a degree which is dependent on the tendency to avoid failure and the intensity of the learning situation.

The interaction of the individual with the learning situation produces achievement (A). In the model, achievement is the sum of the effort expended in the situation as well as successes and failures. Thus, a negative achievement can indicate avoidance. Retention (R) was defined to be the accumulation of skills, knowledge and experience resulting from achievement activity. The schematic indicates an interaction between achievement and retention. This interaction is such that retained information interacts with achievement to produce more retained information. It also affects achievement in such a way as to change probability of success and to influence locus of control. Locus of control, in turn can modify motive to succeed, motive to avoid failure, and probability of success.

The precise nature of interactions is represented by the model in energy language symbols as shown in Figure 17. The definition of each of the variables is as described in achievement motivation theory and the general description of the model. The explanation of the energy model will be done for each variable to indicate how the total system is affected.

In moving from left to right in the model, energy quality increases. Energy quality is the concept that refers to the ability of higher quality energy to facilitate more and more diverse energy interactions than energy of lower quality. Further, small amounts of

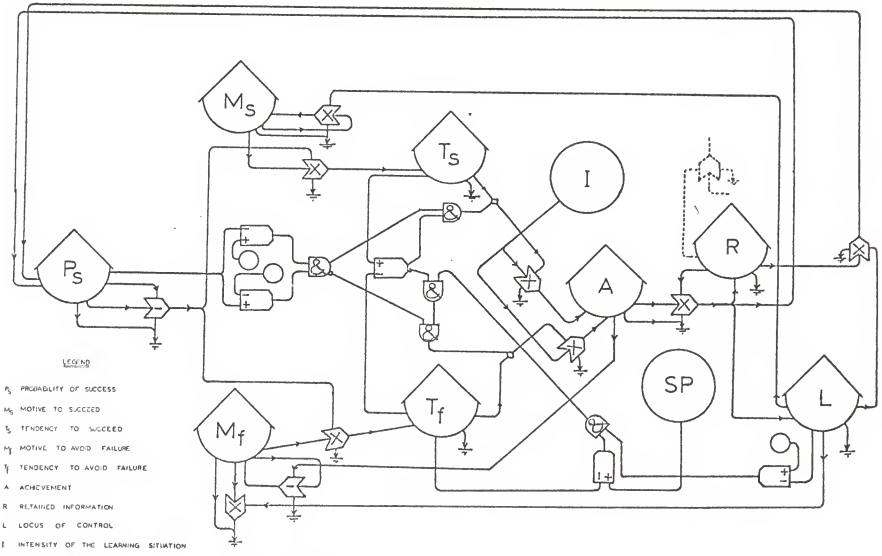

Figure 17: Energy Language Representation of the Model

high quality energy can amplify or substantially increase the flow of lower quality energy. Thus, when energy is fed back from the retention tank to the probability of success tank, the interaction of a small amount of energy can produce fairly large changes in probability of success. This role of energy quality manifests itself in the importance of feedback in systems, whereby feedback of high quality produces substantial changes without utilizing much of the high quality energy.

Flows into and out of each tank are shown by arrows on the lines representing flows. Lines which join tanks with comparators do not act as energy drains or inputs but function only to show what quantities are being compared. The tank representing the variable perceived probability of success (P_s) has two energy flows into it and three out from it. Two flows go to the negative multiplier. These two function to produce the product of probability of success and incentive, or $P_s(1 - P_s)$. The other flow out represents the depreciation of the energetic value of P_s over time, since no quantity of energy can exist for a time period without some depreciation.

One flow into P_s, which results from the interaction of R with A represents the increase in P_s which occurs when the individual, through achievement activity, increases R, that is succeeds in learning. The relationship indicates that P_s can increase, although at a slower and slower rate when large effort is put into achievement even though retention is not high, or may even be decreasing. The other flow into P_s results from the interaction R and L. Thus, if retention and locus of control increase, then probability of success also increases. Since the system is dynamic, changes in other variables may mean total energy into P_s is greater than the energy out so that the value of P_s may

increase. The reverse is equally possible.

There are three flows out of M_s and one in. One flow out takes part in the interaction of M_s with the result of the interaction of probability to succeed and incentive. The result of the interaction produces, in part, the changes in tendency to succeed. The flow out of M_s into the multiplier which has a flow from L specifies the interaction of locus of control with motive to succeed. As L increases, or M_s increases, motive to succeed is enhanced. Should L and M_s decrease, energy flow into M_s would also decrease. The interaction thus gives rise to the flow into M_s. The other flow out from M_s is the depreciation of M_s over time.

The flow into T_s results from the interaction of P_s, incentive, and M_s, as explained previously. One of the flows out is depreciation; the other is an interaction with the intensity of the learning situation. Since the interaction is multiplicative, as T_s increases the energy recognizable as achievement is increased. Decreasing either T_s or I results in a lower flow of energy to A, that is, less recognizable achievement.

Motive to avoid failure (M_f) has four flows out and one in. The flow in results from an interaction of level of M_f with A in a fashion which causes an increase in M_f when A decreases. Thus one of the flows out is a necessary part of this interaction. The flow which interacts with the result of the interaction of probability and incentive produces T_f. Atkinson postulated that tendency to avoid failure depended on the interaction of probability to avoid failure, incentive to avoid failure and motive to avoid failure. However, since $P_f=1-P_s$ and $I_f=-P_s$, the magnitude of the value of $P_s \times I_s$ and $P_f \times I_f$ is the

same. The negative value refers to the avoidance character of the product of P_f and I_f. Since T_s and T_f are compared to see which is larger (discussed later) the model duplicates Atkinson's hypothesis. The drain on M_f which is affected by L indicates an interaction which is such that M_f is drained more rapidly when L is high. Thus when L is large (internal) M_f decreases. The remaining drain is depreciation. For purposes of the model it is shown but is not considered to be significant as compared to the effect of L. It is, therefore, assumed to be zero.

Flow into T_f results from the interaction of probability, incentive, and motive as discussed previously. One of the flows out is depreciation, the other is an interaction of T_f with I to produce some achievement flow. Flows into A have already been discussed in conjunction with T_s and T_f, flow out to interact with M_f discussed in conjunction with M_f, and the flow out to interact with R discussed in conjunction with P_s. The remaining flow out is depreciation of A.

The flow out of R to interact with A has been partially discussed in conjunction with P_s. However, the result of the interaction which produced a flow to P_s also produces a flow to L and to A. Thus as A increases (and R) more energy flows to R and L thereby increasing these as well as P_s. The remaining flow out is the depreciation of R, commonly referred to as forgetting. All flows into and out of L have been discussed except for the flow out due to depreciation of L.

The remainder of the diagram specifies the conditions under which flows occur. The comparators connected to P_s determine the interval for decisions which determine in part whether T_s or T_f will interact with I. If P_s is greater than a lower bound specified and less than an

upper bound, and if $T_s > T_f$, then T_s will interact with I to produce a flow to A. If P_s is less than the specified lower bound or greater than the specified upper bound, and if L is less than a specified value, and if T_f is less than SP, then T_f will interact with I to produce a flow to A. The conditions for flow are dictated by the factors which influence participation for individuals of various types, as discussed previously.

The dotted portion of the model is included to indicate that the energy storages represented in the model can also be connected to other processes not considered. Retention is an obvious variable to use to indicate this, but the same may be true for other variables in the model.

Mathematical Representation of the Model

Utilizing the energy diagram in Figure 17, differential equations which represent the model were derived. The change in any variable is the sum of flow in minus sum of flow out. The symbols used in the equations correspond to the symbol used for the tank in the diagram. The equations are derived in accordance with the examples in Chapter I and are as follows:

$$\dot{P}_s = k_{21}LR + k_{22}RA - k_{23}P_s(1-k_{18}P_s)M_s - k_{24}P_s(1-k_{18}P_s)M_f - k_{20}P_s$$

$$\dot{M}_s = k_{27}LM_s - k_{26}M_s - k_{28}P_s(1-k_{18}P_s)M_s - k_{67}LM_s$$

$$\dot{T}_s = k_{12}P_s(1-k_{18}P_s)M_s - k_{11}T_sI - k_{13}T_s$$

$$\dot{M}_f = k_{15}M_f(1-k_{50}A) - k_{16}P_s(1-k_{18}P_s)M_f - k_{17}LM_f - k_{68}M_f(1-k_{50}A) - k_{99}M_f$$

$$\dot{T}_f = k_{40}P_s(1-k_{18}P_s)M_f - k_{41}T_fI - k_{42}T_f$$

$$\dot{A} = k_{35}T_sI + k_{36}T_fI - k_{39}A - k_{37}M_f(1-k_{50}A) - k_{38}RA$$

$$\dot{R} = k_{43}RA - k_{44}RA - k_{51}LR - k_{52}R$$

$$\dot{L} = k_{31}RA - k_{32}LR - k_{33}LM_s - k_{30}LM_f - k_{34}L$$

Table 2 in Chapter III includes a more detailed explanation of each of the terms. The numbers of the different constants correspond to the various pots on the analog computer representation shown in Figure 18. As already mentioned, the depreciation of M_f was considered negligible as compared to losses produced by the interaction of M_f with L. It is, therefore, not included in the analog version of the model. The final representation is the analog representation of eight equations. Standard analog symbols are used in the diagram of this representation as indicated on Figure 18.

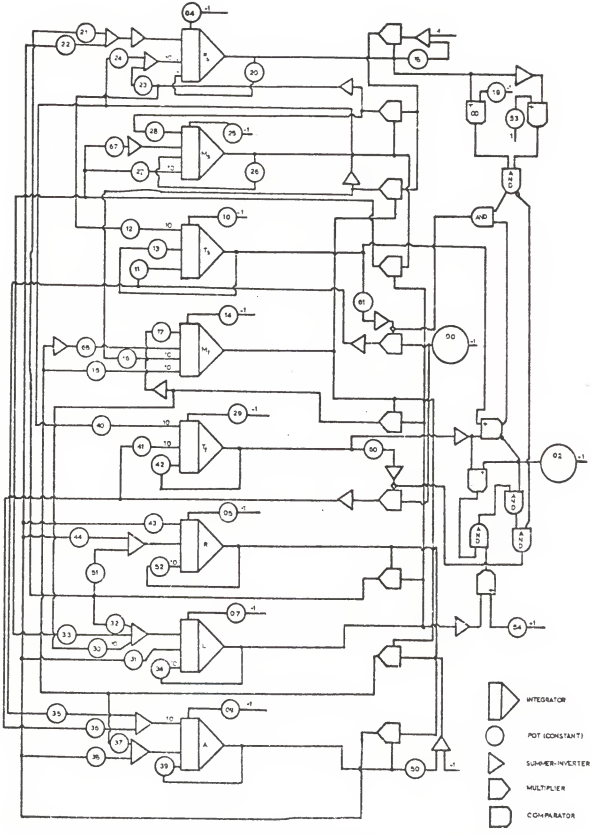

Figure 18: Analog Schematic Representing the Model

CHAPTER III

RESULTS

The analog computer representation of the model shown in Figure 18 was put on the computer. Using the computer, results from the modeling procedure were obtained in two phases. In the first phase, the flows which were necessary to produce results in keeping with predictions made with achievement motivation theory and research findings were determined. The second phase consisted of collecting data for selected variables in the model to determine the behavior of the variables under different initial conditions.

Determination of Energy Flows in the Model

Since the study was conceived, in part, to investigate the usefulness of applying the energy systems approach to modeling an educational situation the procedures used in determining the energy flows necessary to duplicate theory were considered as data or results. Thus the determination of the relationships to be modeled, the energy diagram of the model, the analog schematic were procedures of a conceptual nature. The use of the analog computer to simulate the interaction of the relationships over time was a verification of the conceptual model, even in the initial stages of flow determination and, therefore, provided data about verification procedures.

Data from Initial Procedures

In order to make an estimation of energy flows in the model, it was first necessary to assign maximum values to the variables. The

maximum values for I, SP, M_s, M_f, L, A, and R were stipulated as 100, providing a range of 0 to 100. The range of P_s was from 0 to 1.0. Since T_s and T_f are determined mathematically by the relationship given in the achievement motivation theory, the maximum for these variables was 25 when M_s and M_f were given maxima of 100.

It was then necessary to assign values to those variables which could serve as initial starting conditions in the model. Since two diverse conditions exist, that is, those for whom M_s is high and M_f is low, and those for whom M_f is high and M_s is low, two different sets of initial conditions were necessary to represent the two types of conditions. The assigned initial conditions for the variables are shown in Table 1. These conditions were assumed as representative of the two conditions while at the same time attempting to change as few of the variables as possible. For $M_f > M_s$, P_s was chosen as .1 rather than .9 on the assumption that non-achievers generally would be more likely to perceive most learning situations as difficult rather than easy.

TABLE 1

INITIAL CONDITIONS FOR VARIABLES

Variable	$M_s > M_f$	$M_f > M_s$
A	50	50
R	50	50
I	50	50
L	75	3
M_s	75	10
M_f	10	75
T_s	18.75	.9
T_f	2.5	14.25
P_s	.5	.1

Before flows and initial conditions could be used for simulations with the model, it was necessary to determine the constants which appear in all of the differential equations. A rough determination of the constants was attempted, since having no knowledge about the magnitude of the flows would require an enormous number of manipulations of constants in order to obtain a feasible solution. The estimation of the constants required an estimation of the flows to and from the variables.

Estimation procedures began with a decision to estimate flows for the case where initial conditions were those which pertained to initial conditions for $M_s > M_f$. The flow into A when T_s interacts with I was assigned a value of 7 energy units. Then flows into and out of each tank were estimated. Some procedures followed during estimation were to try to keep the sum of flows into a variable minus the sum of flows out of a variable close to zero if the variable was considered to be relatively stable. If the variable was expected to increase, then those flows which would cause the increase were made larger than they would be if no increase was expected. Likewise, if the variable was expected to decrease, the flows out were larger than would be the case if steady state was expected. In all cases, the flows were estimated so that energy was conserved, that is, that the sum of energy flows into the multiplier equalled the sum of the flows out of the multiplier (the flow out included the energy dissipated). A summary of the estimated flows, the description of the flow by its origination and destination, and the number of the constant associated with the flow are shown in Table 2. Since conditions for $M_s > M_f$ were used as starting conditions these are shown on the table. However, the conditions relevant when $M_f > M_s$ required only

a few changes and the changes are shown in parentheses for the appropriate variables. This makes it possible to show all of the constants and flows for both conditions on one table.

The calculation of the value for each constant was done by using the initial conditions associated with the constant and the flow produced. The initial conditions were the values assigned to the variables (shown in Table 2); the constant was the unknown; and the product of these (as indicated by the flow) was set equivalent to the value of the estimated flow. For example, the flow from the interaction of L and R into P_s had an estimated value of .1 and was represented in the differential equation for P_s by the term $k_{21}LR$. The initial condition assigned to L was 75, and to R, 50. Therefore, $k_{21}(75)(50) = .1$, and the unscaled value for k_{21} is .0000266. In order to scale the constant to account for the difference in the maxima for L, R, and P_s, the following equation was used:

$$k_{(\text{scaled})} = \frac{k_{(\text{unscaled})} \times \text{maximum scale value of energy source}}{\text{maximum scaled value of energy receiver}}$$

The source in this case is the point from which the flow to P_s originates (the multiplier) and the receiver is P_s. The maximum value of the multiplier is (maximum L)(maximum R) or 100 x 100. The maximum value of P_s is 1. Therefore,

$$k_{21(\text{scaled})} = \frac{.0000266 \times 100 \times 100}{1}$$

$$= .266$$

This procedure was repeated for all the constants to obtain an estimate of reasonable starting values for the constants. Scaled values for the estimated flows are also shown in Table 2.

TABLE 2

FLOW DESCRIPTIONS AND CONSTANT VALUES

Constant or Pot #	Flow Description	Estimated Flow	Calculated Value	Actual Value
00	I to T_sxI	50	.500	.500
02	SP	50	.500	.500
04	I.C. for P_s	.5	.500 (.100)	.500 (.100)
05	I.C. for R	50	.500	.500
07	I.C. for L	75 (3)	.500	.500
09	I.C. for A	50 (10)	.500 (.100)	.500 (.100)
10	I.C. for T_s	18.75 (.9)	.670 (.036)	.670 (.036)
11	from T_s to T_sxI	2.0	.001	.001
* 12	from P_sx(1-P_s)xM_s to T_s	2.02	.011	.040
13	depreciation of T_s	0	0	.1089
14	I.C. for M_f	10 (75)	.100 (.750)	.100 (.750)
* 15	into M_f from M_fx(1-A)	1.5	.031	.023
* 16	from M_f to P_sx(1-P_s)xM_f	2.0	.080	.107
17	from M_f to M_fxL	0	0	.772
18	proportion of P_s in (1-$k_{18}P_s$)	1.0	1.0	1.0
19	lower limit for P_s	.4	.400	.400
20	depreciation of P_s	0	0	.091
21	into P_s from LxR	.1	.266	.220
22	into P_s from RxA	.1	.400	.400

Table 2 - continued

Constant or Pot #	Flow Description	Estimated Flow	Calculated Value	Actual Value
* 23	from P_s to $P_s x(1-P_s) x M_s$	.05	.002	.027
* 24	from P_s to $P_s x(1-P_s) x M_s$	.05	.200	.200
25	I.C. for M_s	75 (10)	.750 (.100)	.750 (.100)
26	depreciation of M_s	0	0	.009
* 27	into M_s from $M_s x L$	2.5	.004	.011
28	from M_s to $P_s x(1-P_s) x M_s$	2.0	.107	.107
29	I.C. for T_f	2.5 (14.25)	.100 (.570)	.100 (.570)
* 30	from L to $M_f x L$	.5	.007	.007
31	into L from RxA	2.0	.080	.143
32	from L into RxL	.5	.013	.007
33	from L into $L x M_s$	1.0	.018	.005
* 34	depreciation of L	0	0	.002
* 35	into A from $T_s x I$	7.0	.075	.800
* 36	into A from $T_f x I$	4.0	.320	.800
37	from A into $M_f x(1-A)$	1.0	.204	.092
38	from A to AxR	4.0	.160	.382
39	depreciation of A	0	0	.057
* 40	into T_f from $P_s x(1-P_s) x M_f$	2.02	.081	.017
* 41	from T_f into $T_f x I$	2	.160	.001
42	depreciation of T_f	0	0	.085
43	into R from RxA	2.0	.080	.210

Table 2 - continued

Constant or Pot #	Flow Description	Estimated Flow	Calculated Value	Actual Value
44	from R to RxA	1.0	.040	.004
50	proportion of A in $(1-k_{so}A)$	1.0	1.000	1.0
51	from R to LxR	1.0	.027	.013
* 52	depreciation of R	0	0	.006
53	upper limit for P_s	.6	.600	.600
54	limit for min L	30	.300	.300
65	Reduce 10 gain	.1	.100	.100
66	Reduce 10 gain	.1	.100	.100
* 67	from M_s to M_sxL	2.0	.004	.005
68	from M_f to M_fx(1-A)	1.0	.205	.204

* indicates flow into 10 gain of amplifier

Data from Analog Computer Procedures

The scaled values for the constants were then used as starting values for the analog computer simulation. The constants were manipulated in order to obtain values for the variables over time which were compatible with achievement motivation theory and related research. The research in achievement motivation theory generally covered time periods which are very short. Many different flows were found which duplicated the theory over short time periods but which were not feasible over longer time periods. Non-feasible solutions were considered as those in which one or more variables behave in a manner which is not explainable, or not compatible with computer operation. For example, P_s greater than 1 or less than 0 is infeasible because this situation is both theoretically and logically impossible. Also, values greater than plus or minus 1 overload the computer.

Decisions about which constant to manipulate were dependent on which variables were discrepant or overloading. The depreciation of each variable over time was initially set at zero for all of the variables. Therefore, it was necessary to utilize these flows to achieve a solution. Since it was easier to work from the energy language diagram in order to determine which flows were pertinent to a given discrepancy, the flows on the diagram were labelled with the numbers of the constants which controlled the flows, rather than working from the equations themselves.

The flows were manipulated until a reasonable solution was reached which would duplicate theory and research for the case where $M_s > M_f$. Then the initial conditions of the variables were set for the case where $M_f > M_s$. Once again the flows were manipulated until the results conformed to those expected with reference to theory and research.

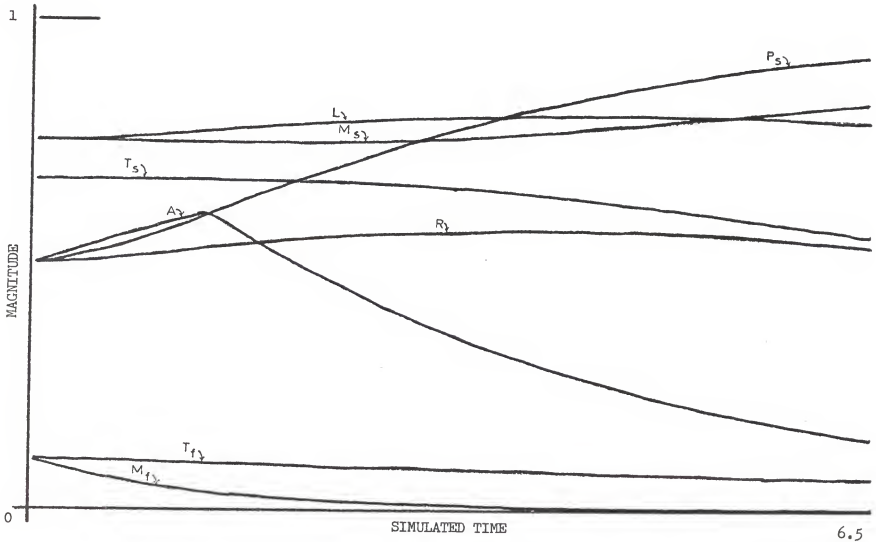

Figure 19: Simulation Using Basic Flows ($M_s > M_f$)

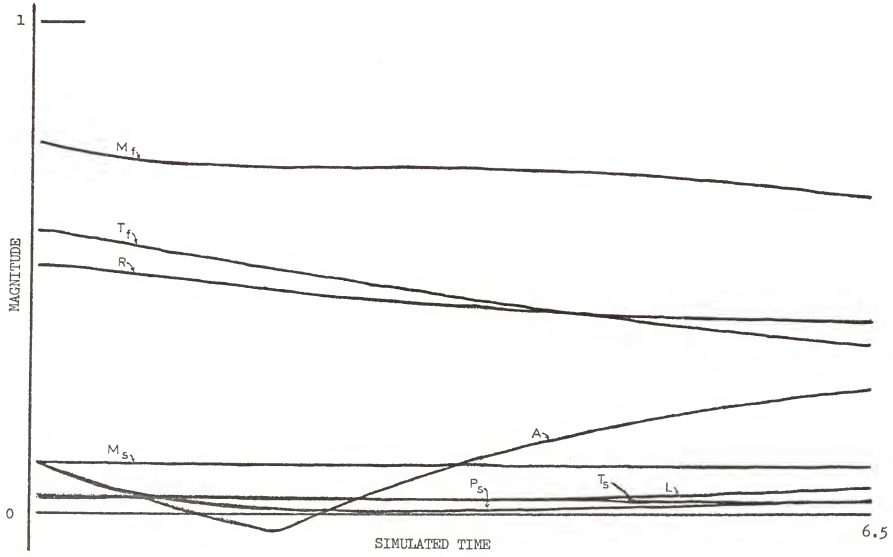

Figure 20: Simulation Using Basic Flows ($M_f > M_s$)

By refining flow rates for the case where $M_s > M_f$ and for the case where $M_f > M_s$, the flow of energy which would provide solutions to both cases was finally achieved. This final set of flows, which were used in the second phase of the study, and which were felt to be those which best produced adherence of the model to theory and research, are shown as actual constant values in Table 2. Values in parentheses are those values which pertained when $M_f > M_s$.

Figure 19 shows the results obtained when the flows shown in Table 2 were used for initial conditions where $M_s > M_f$. Figure 20 shows the results obtained when initial conditions for $M_f > M_s$ were used. In both cases the magnitude of the variables was plotted against time, although in these two figures the time interval represented in the graphs was short, compared to the time during which it was possible to simulate the interactions of the variables under the conditions. The magnitude scale ranges from 0 to 1. Thus the values represented on the graph are the portion of total of maximum value possible for each variable. Simulated time for both figures was 6.5 seconds for the total time scale. This time was important in comparing these plots to the other plots but it had no real meaning because the amount of actual time represented by 1 second of simulated time was not known. Some attempt was made to determine orders of magnitude for the time scale in later parts of the study.

The variables represented in Figure 19 behave as was predicted by the achievement motivation theory. Those for whom $M_s > M_f$, achieved only when the probability was intermediate. The probability of success increased and tendency to succeed functioned in a fashion which adhered to theory, that is, as probability increased the tendency to succeed

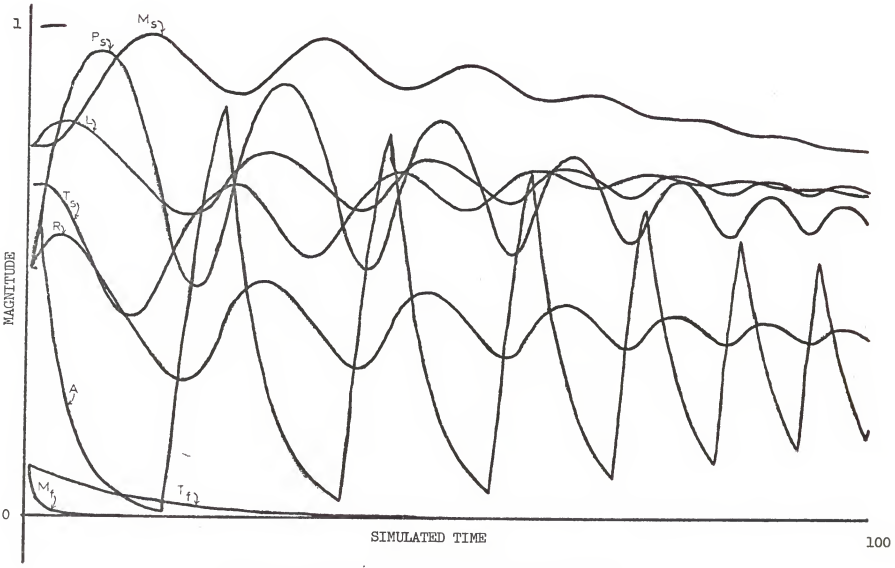

Figure 21: Simulation Using Basic Flows ($M_s > M_f$)

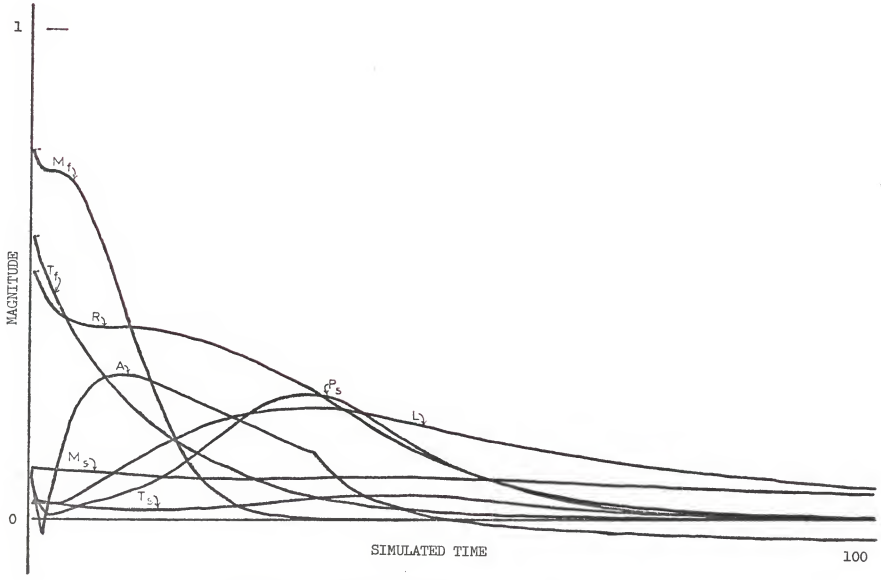

Figure 22: Simulation Using Basic Flows ($M_f > M_s$)

decreased. Motive to succeed and motive to avoid failure were relatively stable. There was a slight increase in retained information, as would be expected as a result of achievement activity. Locus of control also showed some slight variation.

In Figure 20, in which $M_f > M_s$, M_s and M_f were also found to be relatively stable. In this case, social pressure was high enough to encourage entry into the achievement activity; hence, the initial avoidance of achievement, shown by the decrease in A to a negative value, eventually gave rise to some achievement activity. The entry into achievement activity came at the point where T_f was less than social pressure, as the relationships stipulated, and also was attempted when the probability of success was very low, as was predicted. T_f decreased initially in order to satisfy the relationship between motive, probability and incentive. Its behavior was then in keeping with theory in that it decreased when the probability of success increased. Retention showed a leveling when achievement activity increased, indicating the effect of the activity on retained information.

Having determined the flows which would result in a duplication of theory and previous research findings, the model was allowed to simulate the effect of allowing these relationships to interact over a much longer period of time. The results of this are shown in Figures 21 and 22. In Figure 21, $M_s > M_f$ and the initial conditions which pertained for Figure 19 were in effect. In Figure 22 $M_f > M_s$ and the initial conditions which pertained for Figure 20 were in effect. The total simulated time in Figures 20 and 21 was 100 seconds as compared to the 6.5 seconds in the previous two figures. Thus, Figures 19 and 20 are represented in .65 of the time scale used in Figures 21 and 22.

In Figure 21, M_s and M_f were still relatively stable in that they fluctuated about some central point. However, there is a trend toward lower levels for both motives. Analysis of A and P_s indicated that A only increased when P_s was intermediate, and that achievement activity increased the probability. M_s and T_s also functioned in a fashion such that T_s increased when probability was intermediate and decreased when the probability increased. It was difficult to determine precisely whether or not M_f and T_f functioned as expected in this case, because M_f was so low that the result of the multiplicative relationship did not fluctuate significantly.

In Figure 22, M_f and T_f did function as predicted by achievement motivation theory for a short period of simulated time. T_f decreased due to the low P_s, and the avoidance of achievement activity. M_f remained high. However, when achievement activity was begun, and P_s increased, T_f and M_f decreased. This was due to the effect of the other relationships which were expected to affect these variables over time. The maintenance of achievement activity was not possible because the motive to succeed was very low and as T_f decreased below M_s, achievement activity could only be undertaken when P_s was intermediate, something which did not occur.

Study of Selected Variables

When the energy flows which would result in duplication of the theory were obtained, certain variables were selected for further study. These variables were given different initial conditions and the simulation carried out over a time period to see what the simulation would produce in the way of changes in the eight variables. The variables chosen for further study were P_s, R, L, and I. P_s was chosen because achievement

motivation theory considered motive as relatively stable, whereas P_s was considered changeable in different situations. R was chosen because the learning experience focuses to a high degree on retained information. The inclusion of L in the model from research outside the area of achievement motivation theory was of interest because it was an addition to the model and expected to be influential in the outcomes, especially for those for whom $M_f > M_s$. The final variable, I, was chosen because the intensity of learning situation is manipulated by those who teach.

In the study of these variables, the focus was on the changes that different initial conditions of the variables considered would produce, rather than on a continuation of verification of the model. This, then, allowed an examination of how the model might function as an hypothesis generation device. The four variables were manipulated one at a time, leaving all other variables with the initial conditions specified in Table 2. Since initial conditions varied for the instance where $M_s > M_f$ and for the instance where $M_f > M_s$, the four variables were considered for initial conditions in which $M_s > M_f$ initial conditions prevailed and then again for the conditions in which $M_f > M_s$ initial conditions prevailed. There was no attempt in this study to vary the initial conditions of more than one variable at one time.

Simulations When $M_s > M_f$

The four variables were each examined over a range of values for the conditions shown in Table 2. The constants were kept the same for all flows and initial conditions except for the initial conditions of the variable being manipulated. The value which the manipulated variable was given for a given simulation is shown in each figure. All simulation

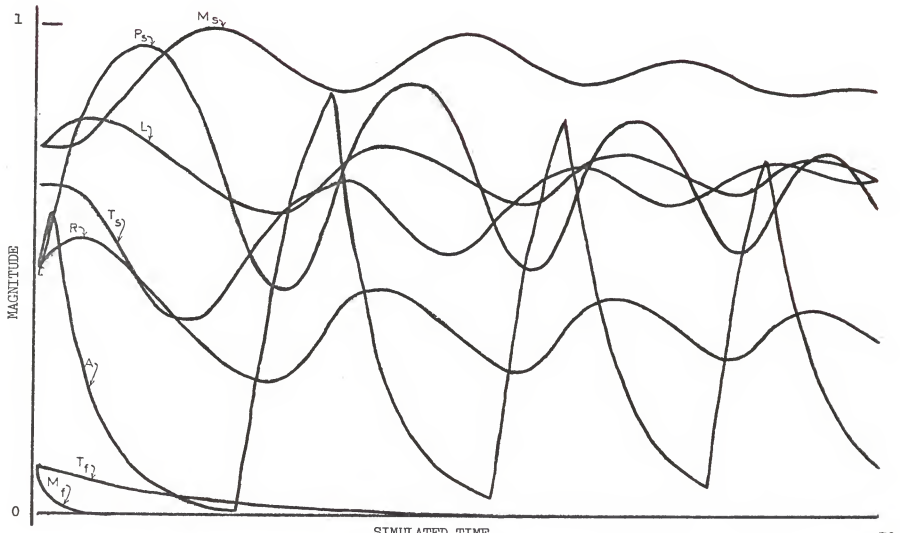

Figure 23: Simulation When $P_s = .48$ ($M_s > M_f$)

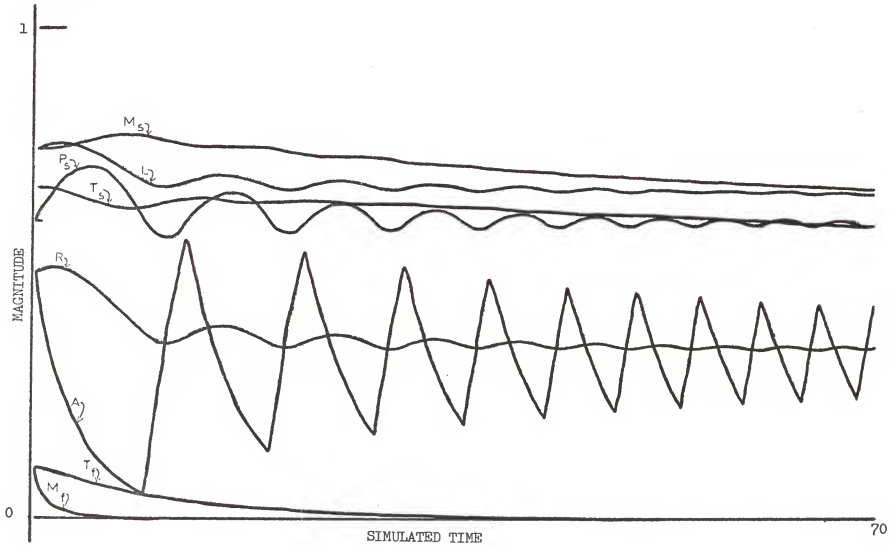

Figure 24: Simulation When $P_s = .60$ ($M_s > M_f$)

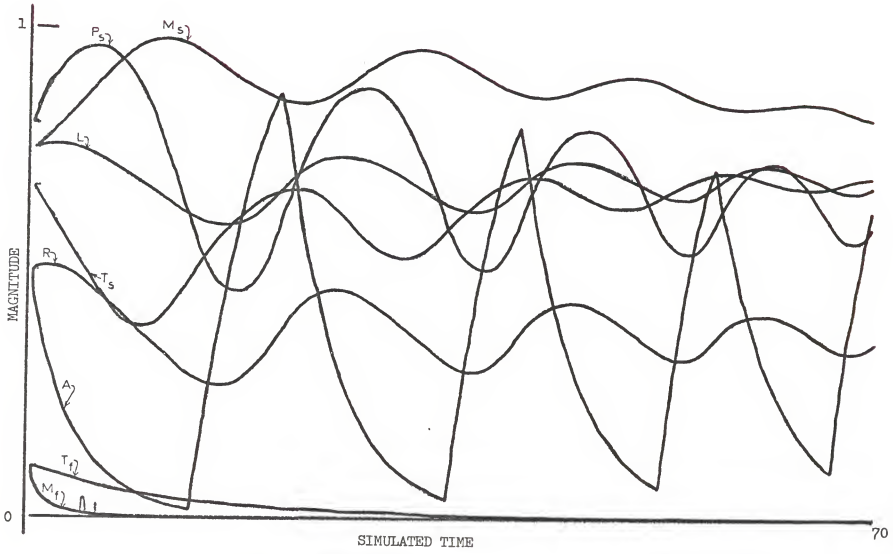

Figure 25: Simulation When $P_s = .80$ ($M_s > M_f$)

times (total time for the x-axis) were 70 seconds. Using 100 seconds was deemed unnecessary because no changes in the 100-second interval occurred which were not evident after 70 seconds.

Figures 23, 24, and 25 show the effect of beginning the simulation at values of .48, .60, and .80 for P_s, respectively. At values of less than .48 and greater than .80, infeasible results were obtained in that M_s became greater than 1, its assigned maximum. In the case of P_s less than .48, the period of time during which achievement activities were being undertaken, because P_s remained in the intermediate range, was so long, that M_s increased beyond its normal maximum. For instances where P_s was greater than .80, very little achievement activity was required to make P_s very high and, hence, M_s again became too large. At $P_s = .60$, there was a minimum fluctuation of all values. This value for P_s was also the maximum of what was considered intermediate range in the model. When tasks were easier than this, it could be seen that achievement fluctuated much more than it did for tasks at $P_s = .60$.

Achievement activity increased initially when P_s was low and then decreased when P_s was no longer in the intermediate range. When P_s increased, initial achievement also decreased before it increased again. As a result, the final outcome when M_s and R were examined indicated that the overall level of these was higher in the case where $P_s = .48$ because of the initial increase in achievement activity. Also, the greatest initial increase of R was noted when P_s was at .48. The largest noticeable difference between the outcomes for all three levels of P_s was that the successive increases and decreases that occurred between M_s, R, L, and A occurred later in the case where the task difficulty resulted in the greatest initial gain in retention and also

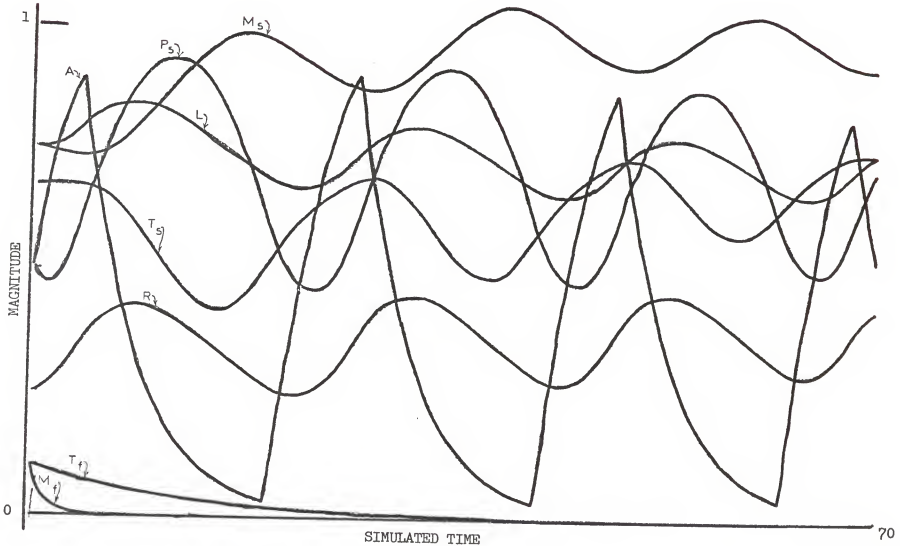

Figure 26: Simulation When R = .25 ($M_s > M_f$)

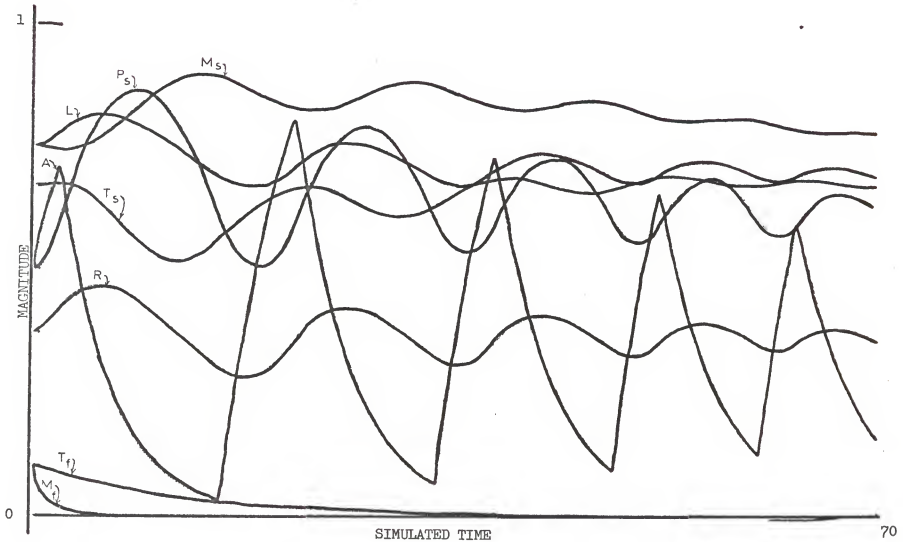

Figure 27: Simulation When R = .37 ($M_s > M_f$)

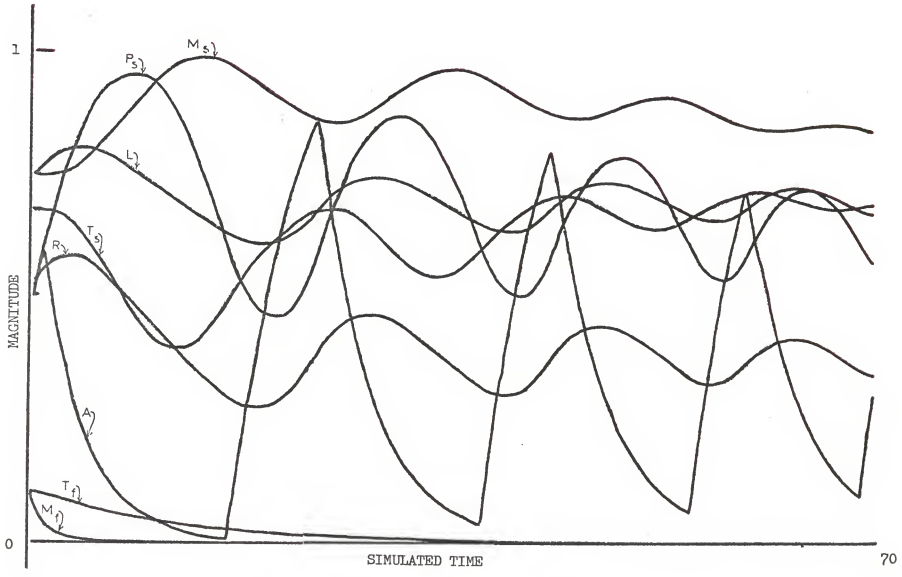

Figure 28: Simulation When R = .53 ($M_s > M_f$)

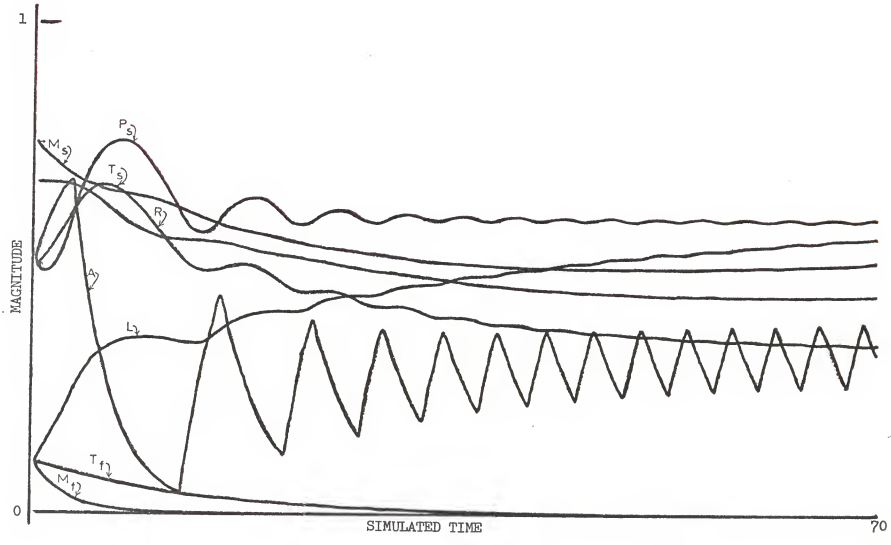

Figure 29: Simulation When L = .10 ($M_s > M_f$)

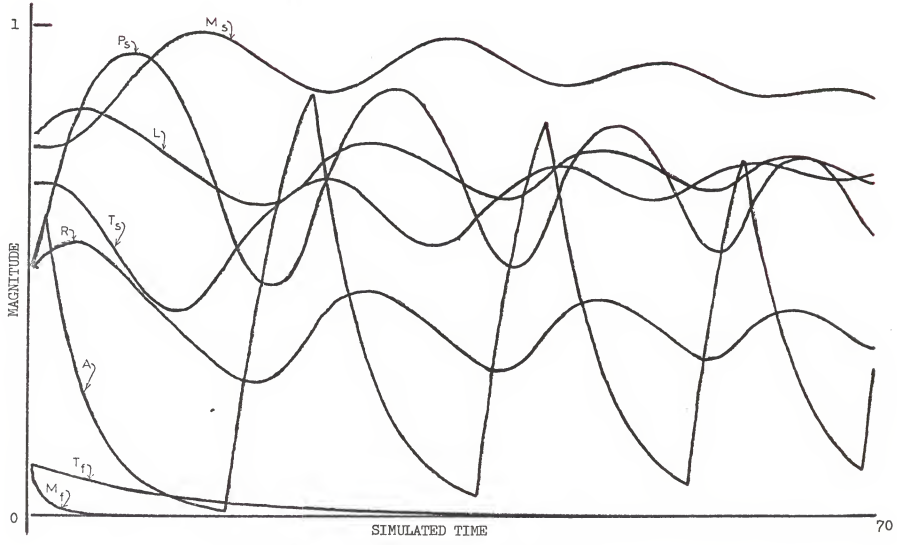

Figure 30: Simulation When L = .78 ($M_s > M_f$)

in the largest maintained gain at the end of the simulation period.

Figures 26, 27 and 28 were obtained when R was manipulated and assigned the initial conditions of .25, .37, and .53, respectively. A value of .25 for R was found to be the lower limit for this variable. When the value was reduced further, M_s produced infeasible results as a result of the long period during which achievement activity was increasing. The value of .53 for R was found to be the upper limit. Beyond this point, the value of P_s became greater than 1 and, therefore, produced an infeasible solution.

The .25 value for R produced the greatest increase in R and M_s as well as the largest initial increase in A. The smallest increase was produced when R = .37, a value intermediate in the range between upper and lower limits for R. A generally decreased with an increase in R. Initial increase in R was also less when the starting point for R was the highest. It was noted that although the oscillations for the variables were not as large when R = .37, they occurred more often than for either the low or the high value for R.

Figure 29 was produced when L was given the value of .1 and Figure 30, when L was assigned the value of .78. Since .78 is not much greater than .75, the value used throughout the study when $M_s > M_f$, the results shown did not differ much from those already mentioned. However, the results obtained in Figure 29 were different from results obtained thus far because of two features. One was the large number of oscillations in A, the other was the large increase in L. No other manipulation of the four variables considered produced such a consistent increase in L for $M_s > M_f$ conditions. There were large changes in L obtained with other initial conditions for other variables, but they

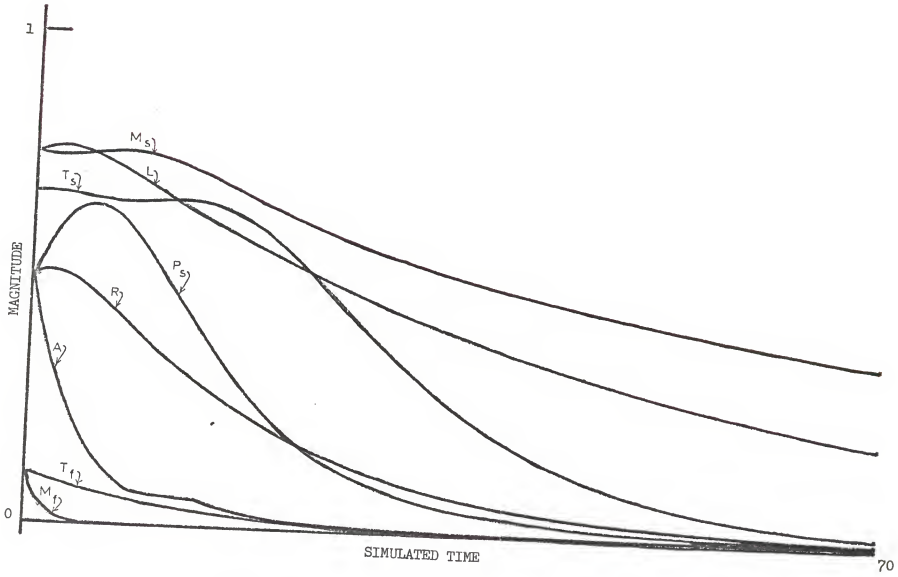

Figure 31: Simulation When I = .02 ($M_s > M_f$)

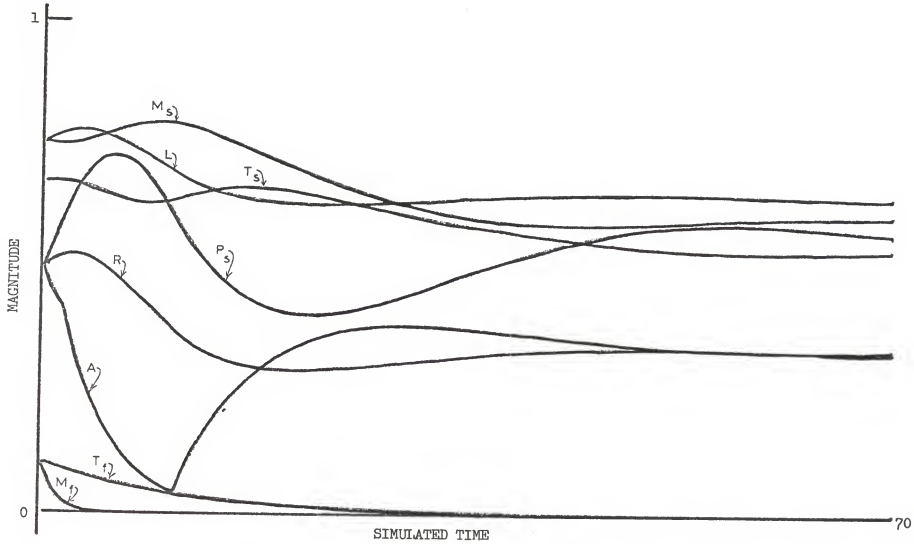

Figure 32: Simulation When I = .16 ($M_s > M_f$)

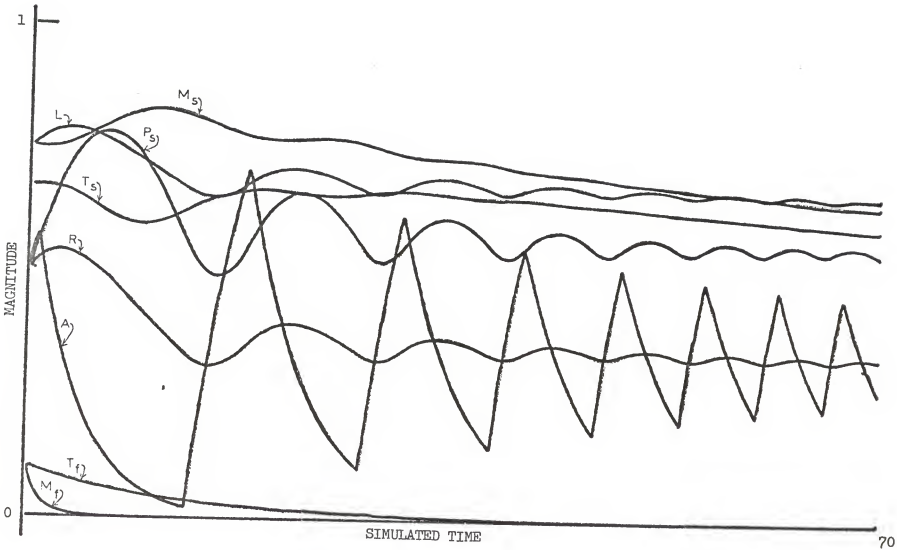

Figure 33: Simulation When Intermediate Range Is .45 to .55 ($M_s > M_f$)

were fluctuations around some mid-point which generally changed very little.

Figure 31 shows the variation of the variables when I was .02 . It can be seen that if the input from the learning situation was very low, in this case almost zero, then all variables showed a decrease over time due to depreciation. Small initial increases were the result of very small amounts of achievement during the time that A was dropping off to zero. Figure 32, which shows the behavior of the variables at I = .16, indicates the lower level at which A is maintained rather than dropping to zero and R, in this case, showed some resulting retained information derived from the learning experience. At levels for I below .16, A dropped off to zero in a similar fashion as shown in Figure 31. Under the conditions of high M_s which pertained in these figures, the maximum value which I could have before infeasible solutions were produced was .53 . At this point both P_s and M_s reached values which exceeded maximum.

Figure 33 shows the effect of reducing the range of P_s in which those with high M_s participate in achievement activity. In this case, the range of probability was from .45 to .55 . Decreasing the range caused the oscillations in all of the variables to be less extreme. Variables leveled much more quickly than when the range was larger. Ranges of more than .40 to .60 resulted in infeasible solutions, as would be expected from theory. Large periods of time during which A, M_s, and P_s were increasing resulted in values which exceeded the maximum in this case.

Simulations When $M_f > M_s$

The four variables were each examined over a range of values for the conditions shown in Table 2, except for those variables for which

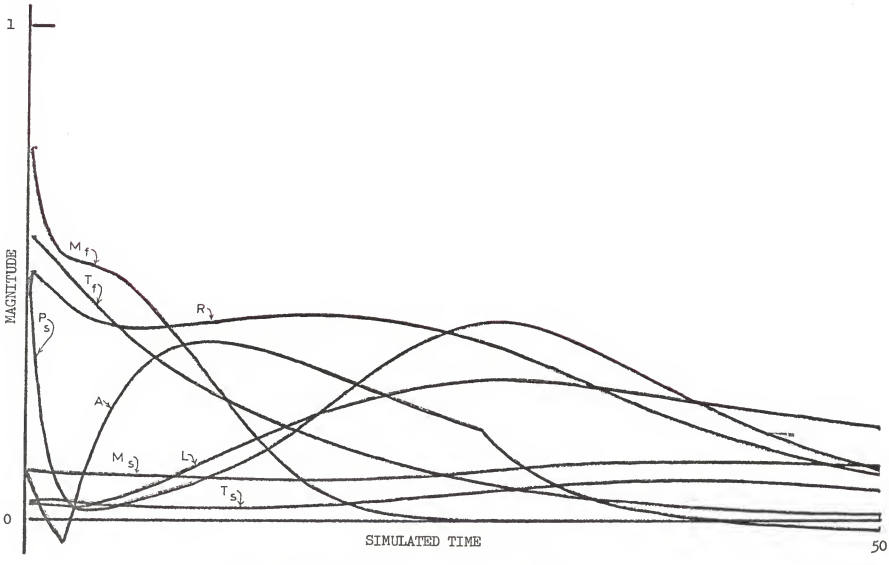

Figure 34: Simulation When $P_s = .50$ ($M_f > M_s$)

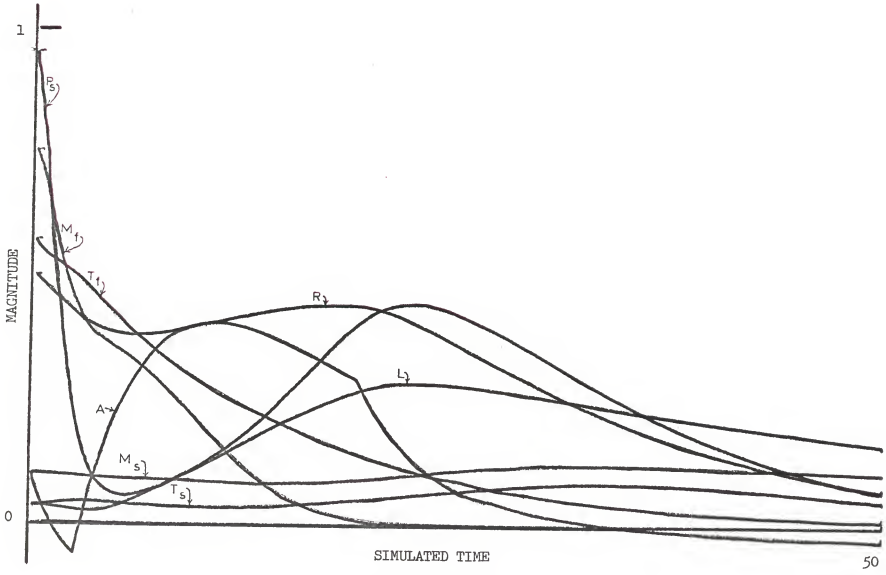

Figure 35: Simulation When $P_s = .95$ ($M_f > M_s$)

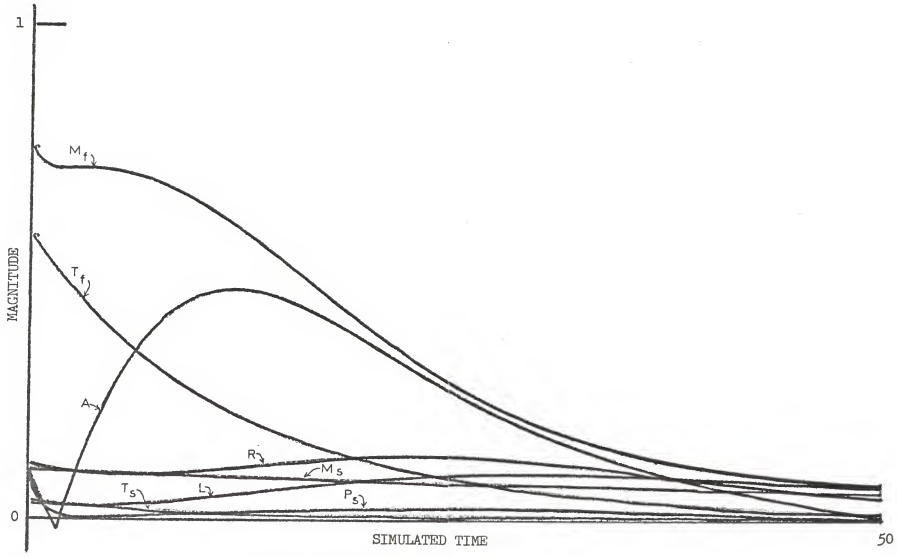

Figure 36: Simulation When R = .11 ($M_f > M_s$)

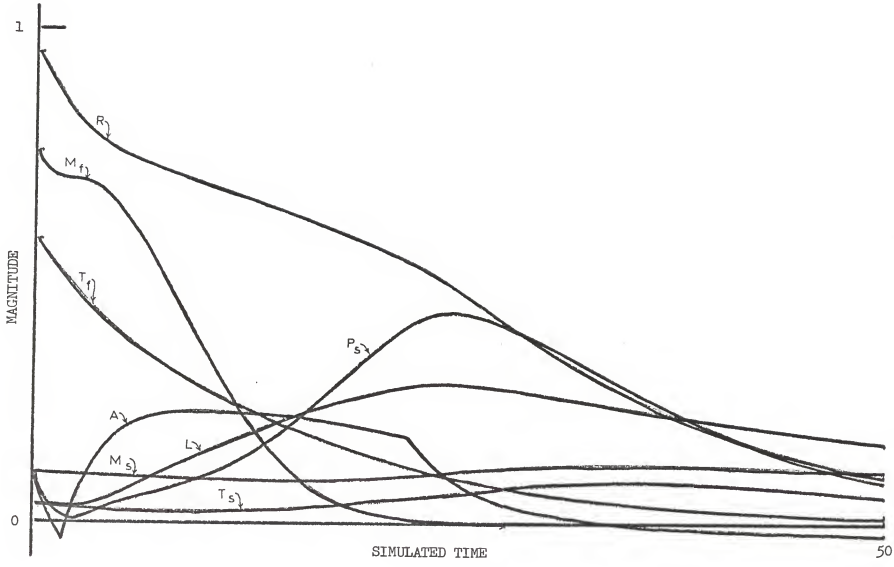

Figure 37: Simulation When R = .95 ($M_f > M_s$)

actual constant values are also present in parentheses. If these were present, then these were the constants used rather than the other constants which represent the values used in the instance when $M_s > M_f$. All flows remained the same regardless of initial conditions being investigated. As in the previous section, all flows and initial conditions except for the initial conditions of the variable being manipulated were kept constant. The value of the initial condition of the variable manipulated is shown on each graph. All simulation times (total time on the x-axis) were 50 seconds. Using 100 seconds was deemed unnecessary because no changes in the 100-second interval occurred which were not evident after 50 seconds.

Figures 34 and 35 show the behavior of the variables when P_s was .50 and .95, respectively. Comparison of the two graphs showed that M_f remained high much longer when P_s was .50 than when the task was very simple (P_s = .95). In conjunction with the longer maintenance of high M_f, A was also maintained for a longer time than was the case for the easier task. This was due, in part, to the fact that P_s did not increase toward intermediate levels as rapidly when P_s was .50 . Concomitantly, M_s increased as achievement activity was undertaken and eventually exceeded M_f. At this point, social pressure did not affect A. The difference in R was not great when the two probabilities were compared, although at the end of the 50-second simulation, R was slightly higher for P_s = .50 .

Choosing different initial conditions for R resulted in the changes shown in Figures 36 and 37. In Figure 36, R was low (.11), and in Figure 37 R was very high (.95). R does not show an increase for high initial R; in fact it shows a rather steady decrease. However,

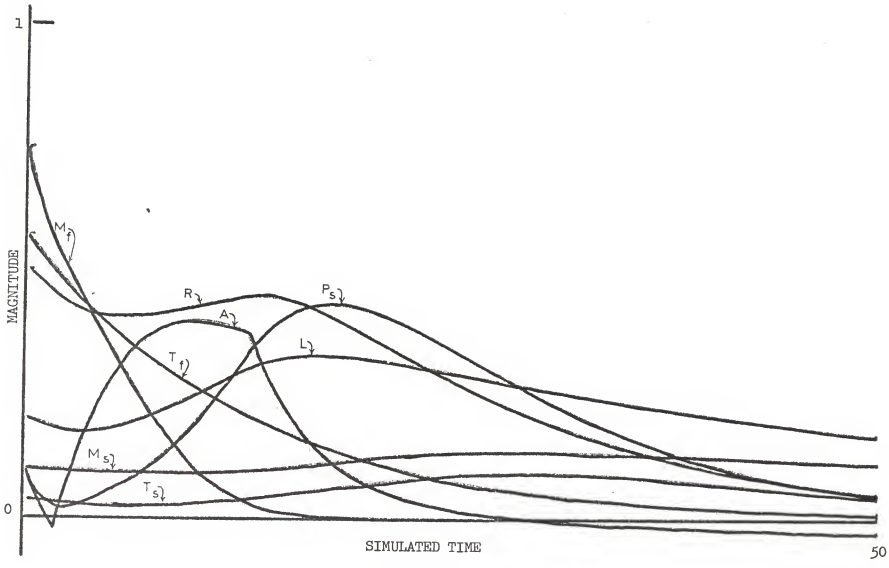

Figure 38: Simulation When L = .20 ($M_f > M_s$)

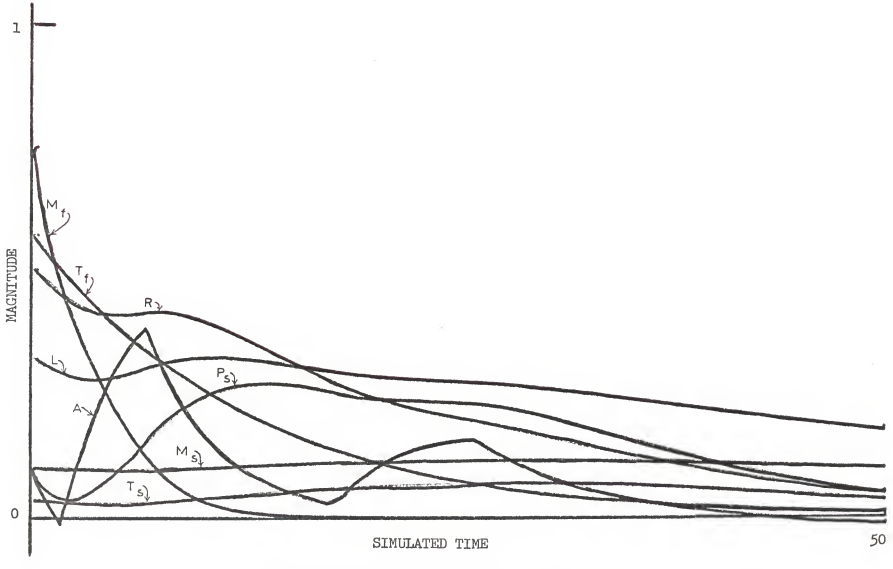

Figure 39: Simulation When L = .32 ($M_f > M_s$)

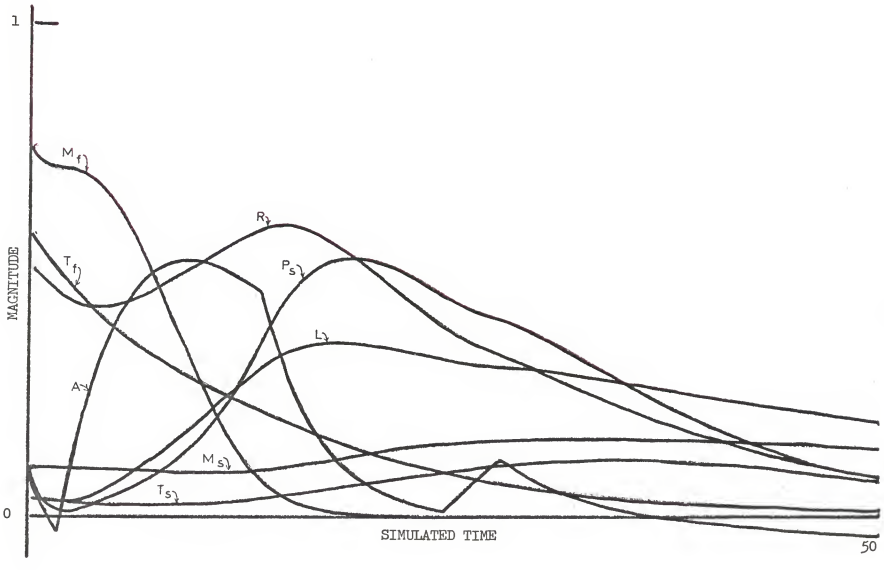

Figure 40: Simulation When I = .50 ($M_f > M_s$)

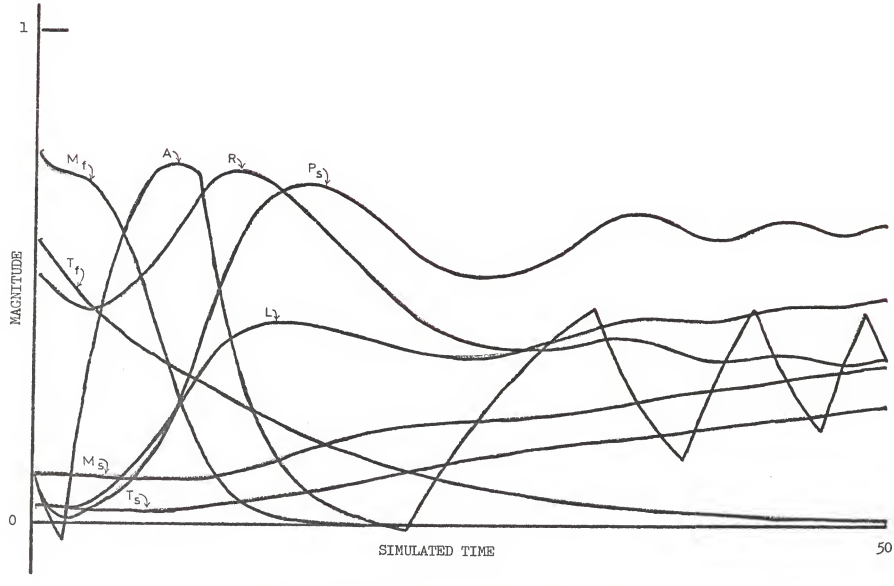

Figure 41: Simulation When I = .95 ($M_f > M_s$)

when the initial R was low, R did show an increase as a result of achievement activity. Even though A increased rapidly at low initial R and reached a value which is higher than the value for A when R is high initially, the effect of R on P_s, M_s, and M_f is evident. P_s and M_s did not increase much, in fact M_s decreased for low R. M_f, on the other hand, remained high for a longer time at low initial R, whereas M_f decreased more rapidly when initial R was high.

In Figures 38 and 39, the initial conditions of L were manipulated. The initial condition for L was .20 for Figure 38 and .32 for Figure 39. As L was increased to .20 from the original .03 used in the verification of the model, increased L caused increases in P_s and A, a more rapid decline in M_f and less retention of information. When L was set at an initial condition of .32, this represented a condition in which L was set above the limit considered as being a low L. The avoidance of achievement (negative A) was not nearly as great for the higher L; that is, social pressure was influential sooner and resulted in less delay in A. This resulted in a more rapid decrease in M_f, but not in more retained information or higher P_s, although P_s was maintained at a higher level for a longer period of simulated time.

The manipulation of the initial conditions for I is shown in Figures 40 and 41. I = .50 was used throughout the rest of the study, and reducing I to .41 resulted in an infeasible solution because A assumed negative values which were greater than the maximum for A. Figure 40 shows the changes in the variables for I = .70 and Figure 41 for I = .95 . Increases in I produced increases in A, P_s, R, L, M_s, and T_s while M_f and T_f declined more rapidly as I increased. At I = .95, some changes produced were of particular interest. At this intensity

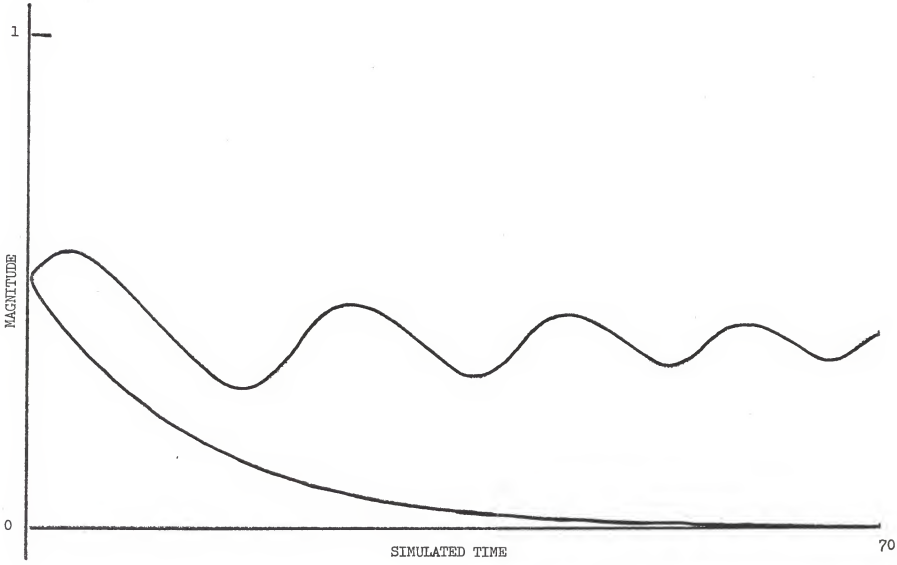

Figure 42: Simulation of R With and Without Input ($M_s > M_f$)

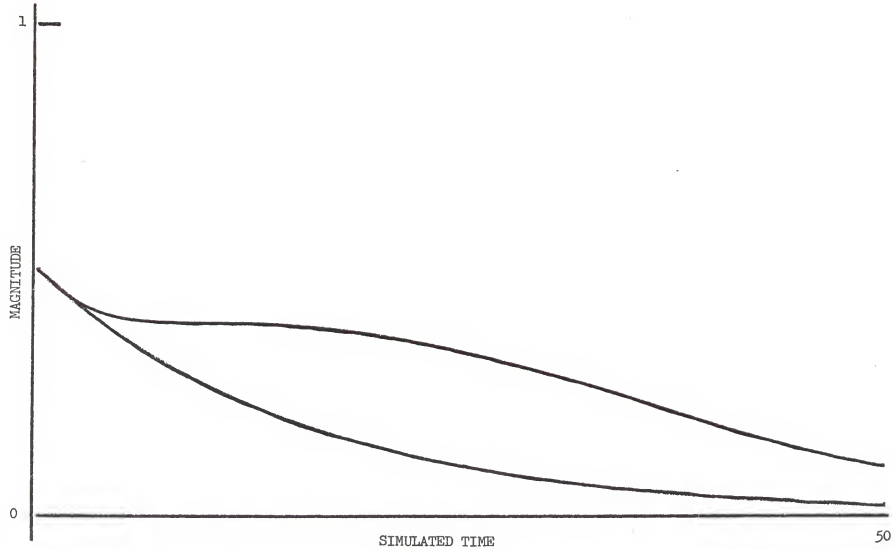

Figure 43: Simulation of R With and Without Input ($M_f > M_s$)

for the learning situation, the large increases in A and P_s, which produced larger L, M_s, and T_s, were sufficient to make $M_s > M_f$. Since P_s was greater than .40, the behavior of the variables changed from that typical of high M_f to one typical of high M_s. Thus, the high I resulted in a change from non-achievement tendency to an achievement tendency.

Although changing the size of the interval considered as intermediate P_s influenced variables when $M_s > M_f$, this was not the case for $M_f > M_s$. If the intermediate range was .10 to .90, then some changes occurred, but since this was an infeasible solution for $M_s > M_f$, it was not considered feasible when $M_f > M_s$.

Figures 42 and 43 show deterioration rate, or forgetting, with respect to R. Thus Figure 42 shows the effect on R when achievement activities occurred, and also when their effect was not allowed to influence R, for the situation where $M_s > M_f$. Figure 42 shows the same information for the situation where $M_f > M_s$. Examination of the normal forgetting curve was considered as a possible technique for determining the actual time represented by simulated time. By assigning a time required for R to depreciate to one-half of its original value, a time value for simulated time could be calculated. The forgetting curves seemingly differ in examination of the two figures. This is an apparent difference only because the time is 70 seconds for Figure 42 and 50 seconds for Figure 43. Depreciation rate per second was the same for both figures.

Thus, in terms of the results obtained from the simulations, the data reported here appear to be consistent with predictions made from achievement motivation theory while also providing information concerning the usefulness of the energy system approach to modeling an educational situation.

CHAPTER IV

DISCUSSION AND IMPLICATIONS

Summary

The relationships which represented the achievement motivation theory were combined with concepts of social pressure and locus of control. These were then represented by an energy systems model using principles and symbols from Odum (1971). The energy diagram of the model was translated to the equivalent differential equation representation and patched on an analog computer. This enabled the simulation of the interactions of the relationships over time. When estimates of the flows in the model had been made as the starting point for the simulation by computer, the process of determining the flows which would allow duplication of the achievement motivation theory was accomplished on the computer.

It was found that the model would duplicate findings from studies which used the theoretical relationships which were modeled. In simulated situations where M_s was high, A increased when P_s was intermediate and M_f and M_s were relatively stable. T_s and T_f fluctuated according to the relationships expressed in the theory. A affected P_s in the manner expected. A increased; P_s increased and vice versa. R was also found to increase slightly as a result of the increase in A.

For simulated situations where M_f was high, the simulation produced results which also duplicated research findings. The relationships between A and P_s functioned as in the case where M_s was high,

except that avoidance was shown when the values of P_s were intermediate. T_s and T_f remained relatively stable. R decreased slightly because of the avoidance of the achievement activity.

When the simulation was carried out over a longer time period, the relationships still functioned as predicted. However, M_s was not a stable trait as was postulated in the theory, rather it was found to be dependent upon A and R. A major difference in the variation of variables was evident when M_s was high as compared to the variation when M_f was high. Under conditions in which M_s was high, A, P_s, L, and R began to oscillate about some level which the variables reached during the simulation. This was not true under conditions of high M_f. In this case, there was a trend toward zero for the variables which oscillated in the other case. A time lag between responses to change of associated variables was also noticed. The response of A to increased P_s was delayed rather than immediate. This was also the case for R, which increased after A increased.

Having duplicated the relationships which were derived from research and achievement motivation theory, four variables were chosen and manipulated in order to ascertain what would occur if these relationships were to pertain over a longer time period. The variables chosen for manipulation were P_s, L, R, and I. These were manipulated one at a time while all others were kept constant. The energy flows determined in the first part of the study were utilized and kept constant also.

For the conditions where M_s was high, manipulation of P_s produced variations in the oscillations of P_s, R, L, and A. The minimum oscillations in these variables were produced when P_s was .60, the maximum value considered in the model to be in the intermediate range of

probability. Initial R increase was greatest when P_s was at its lower limit for the initial conditions of the variables in the model. Manipulations of the initial conditions for R produced changes in the variables which indicated that the greatest increase in R and M_s was at low initial R. Intermediate values of R produced less increase in R and M_s but more oscillations than did the high or low initial conditions of R.

When locus of control was manipulated, greatest increases in L were found when initial L was low. In this case, initial increase in A was also large. As L increased, initial increases in A were less than those at the low level of L, and the number of oscillations in the variables were less. Increasing I increased the number of oscillations and slightly decreased the magnitude of the fluctuation of the oscillating variables. When I was very low, a tendency toward normal depreciation of the variables was observed, since there was little to influence achievement activity.

Simulations done for the conditions when M_f was high produced somewhat different results. The manipulation of P_s indicated that A was maintained longer for more difficult tasks. R was also slightly higher for these tasks. However, M_f remained high longer when the tasks were more difficult. Changing the initial conditions for R to a low initial value produced achievement over a longer period of time. M_f also remained high longer. P_s, in this case, did not change much. For high initial R, M_f and A decreased rapidly and P_s increased rapidly.

Manipulations of L were constrained by the value considered in the model as the value below which L would be considered as 'low'. When L remained below this, increasing L produced increases in P_s and A

and decreases in M_f as well as smaller initial gains in R. When L was increased above the 'low' value, A and P_s increased much more rapidly, M_f decreased rapidly and initial gains in R were increased. The manipulation of I produced some of the most dramatic changes. Increasing I brought increases in A, P_s, R, L, and T_s, and decreases in M_f and T_f. When the level of I was very high, the changes in the variables were such that T_s exceeded T_f, P_s became intermediate, and the oscillations typical of the high M_s conditions replaced the general decline conditions common to the high M_f conditions.

Discussion

The purpose of the study was threefold. One aspect was to determine whether the energy systems approach could be used to model educational systems. The second aspect was to examine the results produced from simulations using the model to determine whether these results adhere to what is already known from previous research. The final aspect of the study was to attempt to identify the features of the modeling process which might have utility in educational endeavors. The results are discussed in the following section by focusing on the four general research hypotheses stated for the study.

Hypothesis 1

Hypothesis 1 stated that the energy systems approach can be used to model the selected educational system. The findings in relation to the utility of the energy systems approach to modeling are discussed in two parts -- features which conform to theory and research and features which are discrepant or infeasible. The model was found to duplicate theory and research well over the short time period represented by Figures 18 and 19. P_s increased with an increase in A

and decreased with decrease in A. Motive, incentive, and probability functioned to produce tendency as was predicted. M_s and M_f were relatively stable, and the logic system in the model did function to delineate the intermediate range of probability to determine whether the tendency was to undertake or avoid achievement activity. A behaved as would be predicted. It indicated avoidance and participation.

There was some problem with interpreting what could be considered 'relatively stable' with respect to M_s and M_f. If relatively stable is a fluctuation of one standard deviation from the initial starting position, then reference to Figures 19 and 20 indicates that the fluctuation was within the bounds of one standard deviation. Atkinson (1965) does not indicate what limits are put on 'relatively stable'. Since the TAT and the Mandler Sarason Test Anxiety Scale are inferential types of tests, the fluctuation of M_s and M_f over the short time period shown in Figures 19 and 20 are feasible.

Over longer periods of simulated time, it was found that M_s was still a relatively stable characteristic. This was not true for M_f. However, Holmes' (1971) study, Clarke's (1973) review of measures of achievement motive, and the findings of Hersh and Schiebe (1967) and Crandall and Lacey (1972) all dealt with those for whom M_s is dominant or found that those for whom M_s is dominant were the individuals who had certain predictable characteristics. This would suggest that M_s is relatively stable and its presence in an individual as the dominant motive does allow predictable types of personality because of the stability of M_s. On the other hand, M_f can be influenced as indicated by other research. It was these influences which gave rise to the relation-

ships in the model which resulted in the instability of M_f. The relationship of anxiety and the outcome of efforts expended in the task may well change anxiety level. Inference of M_f from test anxiety, as measured before the test, does not indicate what the level of anxiety is after the test. Thus, the nature of the instrument used to infer M_f may lead to the belief that M_f is stable because the anxiety level may be the same before each test, but very different between tests. The relationships included in the model would indicate that M_f is task dependent and not as stable as Atkinson had postulated. Increases and decreases in A did affect M_f.

Some combinations of initial conditions were found which resulted in infeasible solutions. These instances will be discussed here since they may be a limitation of the model. There is great latitude in the choice of initial conditions at which the simulation begins. This range of conditions available may make it possible to combine conditions in the model which are not in this combination in individuals. For example, the upper limit for L in individuals with high M_s was .78, or 78 percent of the total range of L possible. It may be that an individual with high M_s and with a locus of control that is higher than .78 is a non-existent type of individual. There is some justification for such an argument. An L of 1 or almost 1 would mean, theoretically, that the individual was sure that he could control the outcome in all situations. Since achievement-oriented individuals choose intermediate probabilities, there is already good evidence to indicate that the idea of almost absolute control of situation outcome is not part of the high M_s individual's characteristics.

Discrepancies in the model may also exist because the relation-

ships are incomplete. This does not mean that the theory is incorrect, or the model simulating the theory is incorrect. The achievement motivation theory was derived from using college students for much of the original experimentation. Almost all of the studies which were reported in Chapter II used randomization of subjects to groups, or there was a range of individuals with high M_s in the sample. Thus, the few individuals who were at the extremes of the sample are somewhat neglected when means and standard deviations were used in analyses. The theory, then, becomes based on a normal distribution, and focuses on the mean. The model too focuses on the 'average individual' by adjustment of the initial conditions and there is no provision in the model for taking into account other features of ability which are operative and not represented well by the variable 'R'. Some variables which serve as limitations to relationships may also exist for conditions when values are at the extreme range of possibility, but these do not function in this model.

There is some reason to suspect that in choosing initial starting points for simulation, the assignment of the value of L and R, particularly, was too large. In cases where L decreased to its final level, this level was close to the values which L achieved in cases where L increased. Figure 40, where the simulation sought its own level for L indicated that the level reached is not nearly as high as the one used as initial condition. This may be true for R also, since maximum increases in R occurred when R had an initial value less than the one used.

Intensity of the learning situation is a constant source of energy in this model. In reality, the learning situation may not be a

constant energy source, but a pulsed source, or a randomly intermittent source. Changing I to the pulsed rather than continuous source may cause the model to conform in more instances. However, the model may be an indication that the discrepancies are indicative of conditions which exist, rather than inadequacies of the model. Verification of some of the changes which the simulation indicates occur would provide an indication of how reliable the model is in showing changes over time.

Hypothesis 2

Hypothesis 2 stated that the model is useful in investigating combinations of relationships which have not been empirically investigated, providing an indication of what might be expected. The variable L and its effect on M_f was suggested by research because of its connection with anxiety. The effect of M_f on the results of achievement activity was also investigated and postulated in the model. The result was to make M_f an unstable characteristic, rather than the stable one postulated. M_f became dependent on time and the individual's performance in the situation.

The manipulation of the initial conditions of the various variables which were examined also indicated that manipulation of the intensity of the learning situation was the only case where it was possible to change the general tendency of the variables over time from the fluctuations which were common in high M_s individuals to those of high M_f individuals, or the reverse. Low I caused the transition from success type oscillations to depreciation of the variables. High I caused the change from the depreciation type of variation common to the individuals of high M_f to the oscillations common to the other

type of individual. This feature has not been researched empirically.

The model also indicated that there is an optimum level for the variables in many instances. P_s was found to be optimal at intermediate level, as was R and L, when the conditions of high M_s prevail. When the conditions represent high M_f instances, then optimal levels result in improvement toward more of the characteristics of the high M_s conditions. The model also indicates that dramatic changes require high energy, as evidenced by the large I necessary to cause complete changes in high M_f characteristics to those representative of high M_s.

Hypothesis 3

Hypothesis 3 stated that the model can be useful as an hypothesis-generating instrument. Changes in all of the variables produced by the manipulation of the variables chosen indicated that hypotheses can be generated from this model. The hypotheses are of two types, those which are necessary in order to verify the changes which are indicated by the simulations using the model and those hypotheses which are indicated because of the changes which occur.

A suggested hypothesis which arises from the model is that there is an optimum combination of variables which produce the greatest change in R. These could be stated in pairs, such as there is a best combination of M_s and I which produces the maximum increase in R. The model indicates that if I is high, M_s should be smaller than the level used in the model. The results of the simulations also indicated that the values used for the initial conditions for M_s and M_f were near the limit under which the relationships pertain. Therefore, an hypothesis suggested is that individuals for whom there is a large difference in M_s and M_f are less likely to achieve under the conditions

represented in the model than are individuals in whom there is not as great a difference in the two motives. These hypotheses are speculative, and depend upon the validity of using the changes indicated by the model. Thus, the model requires some verification before these hypotheses can be of real value. The types of hypotheses necessary to determine the validity of the simulations are discussed under implications, as are some other important hypotheses generated from the simulations.

Hypothesis 4

Hypothesis 4 stated that energy systems models can be useful for theoretical speculating about relationships between variables in educational situations. Again, the validity of this hypothesis is determined by the validity of the changes which the model indicates occur. They are, therefore, most valuable at such a time that the model has been verified in empirical studies. However, indications of the usefulness of the energy systems approach can be pointed out in lieu of the verification of model validity which must be attempted in further study.

The use of the Darwin-Lotka Law (Odum, 1971) in the analysis of educational situations appears to have some utility. As already pointed out in Chapter II, the relationship between incentive and probability appeared to be an instance of the operation of maximum power principle. In this case, power was considered to be maximized at intermediate levels of difficulty. When R was manipulated, it was found that the intermediate value of R in the range which yielded feasible results was also the value for R which resulted in the maximum increase in the other variables.

In biological systems, systems which maximize power and which achieve some steady state dominate those systems which do not maximize power. There were two indications of this in the data from the study. The first was that the system commonly thought to be the successful one, that is the instance where M_s is dominant, has the appearance of a steady state. The steady state is typified by the oscillations of the systems as it utilizes the energy. In these instances the energy is utilized in different parts of the system and fluctuations about some level indicate the maintenance of the stored energy to make up for the losses due to depreciation.

Another major indication of the utilization of the maximum power principle was when sufficient energy was supplied to the system and the system utilized the energy, the behavior of the storages then took on the characteristics of steady state. This was the case when I was very large and M_f was dominant. Sufficient energy was supplied and its utilization resulted in conditions which were similar to those in which M_s was dominant. The system then became a successful system because the energy was utilized more efficiently.

Also of interest from the point of view of energy systems theory is the appearance of time lags when there were operations occurring between storages. An increase in A did not produce an immediate increase in P_s or in R. Instead some time lag was evident. This time lag is not given attention in the formulation of the achievement motivation theory. If time lags do exist this has implications for research methodology.

Depreciation of variables over time has been evident in the case of retained information. However, only a few variables have

received attention with respect to depreciation. Energy systems theory would indicate that all storages depreciate, some more rapidly than others. This depreciation may be of value in investigation of which variables are relatively stable. The stability postulated for M_f was not found in the simulations because the depreciation of M_f was dependent upon L and A.

Implications

The implications of the information acquired in the study are twofold in nature. There are immediate implications for further study in attempting to determine the validity of the model and the changes in variables over time which the simulations produced. The other realm of implications applies should the outcomes indicated by the model be found to be true after empirical testing. These implications are for experimental design and for the procedures with which we currently look at variables in education.

Immediate Implications

A series of empirical investigations are envisaged to determine the validity of the model. These would determine the time scale for the model using the information similar to that shown in Figures 42 and 43. Such studies would require that the time taken for the normal depreciation of retained information for a given situation be determined. Knowledge of this nature would indicate not only the time scale of the model but also the time lag for the variables used in the model, specifically A and R.

With prior knowledge of the time scale, it could be empirically determined whether or not variables such as A and R do fluctuate about some median level for those persons for whom M_s is dominant. The

investigations would also indicate whether or not there is a time lag as indicated in the simulations.

The simulations indicated that M_f was not stable, but rather that it was a function of A and R. Studies in which M_f was measured at intervals during an achievement activity would indicate whether or not M_f is stable. These experiments would need to utilize those individuals for whom M_f is dominant and L is low in order to provide information about the validity of the model. Another type of empirical investigation which would indicate model validity would be to determine whether or not intense, structured learning experiences do produce a change from the dominance of M_f to conditions in which M_s is dominant.

Other Implications

Should the model prove valid, there are implications for research methodology which are of importance. Validity of the model would suggest that investigations into the nature of retention of learned information must take into account the time lag which exists between maximum storage in different variables. Thus, experimental procedures which utilize procedures in which R is measured at a time when A is at a peak do not provide true information on R because there is the time lag between A and R. Knowledge of the time scale indicated by the simulations would provide a key to the length of time which might enable the measurement of maximum retention after achievement has reached a maximum.

Some of the simulations resulted in more oscillations which were less severe than were found in other simulations. These fluctuations may be the indicators of the conditions which provide optimal

utilization of energy and thus also indicate when conditions have been achieved which provide maximum power. Maximum power conditions may be indicated by many small oscillations rather than fewer large ones. In the learning situation, maximum power could be referred to as greatest retention in the smallest time period.

In order to put empirical data from educational systems into the model and thus provide empirical indications of the results of specified interactions, it is necessary to find some means for measuring energy flows between variables in some fashion. Should some technique be found, this would not only be another way of providing some validity for the model, but it would also be a powerful predictor as a research tool, predicting both changes and expected magnitude of the change in a given period of time.

Prior to the establishment of the validity of the predictions made by simulations with the model, it still remains that the model was able to duplicate research results well in theoretical mode rather than as an empirical device. It, therefore, suggests examination as a tool whereby theoretical constructs and relationships can be manipulated in order to see what changes occur and whether or not these changes are reasonable. In this respect alone, it has value as a means for manipulating a number of relationships simultaneously when it becomes impossible for these manipulations to be done mentally.

The existence of relationships which indicated that the maximum power principle is operating in educational situations may also indicate that other such relationships exist. This is of importance in that many predictions in educational situations are done on the assumption that relationships are linear. The simulations using the

model indicated that non-linear relationships and the maximum power principle are useful in the consideration of successful systems and may be of utility as theoretical constructs in education.

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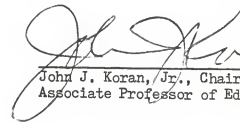
He has served as a computer programmer and statistical consultants for various projects, has published several technical reports and articles, and presented papers at local and national conventions. He is a member of the American Educational Research Association, the National Association for Research in Science Teaching, and the National Science Teachers Association.

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.



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